SHEET-METAL WORK

A PRACTICAL TREATISE DEALING WITH EVERY PHASE OF THE SHEET-METAL INDUSTRY, INCLUDING MATERIALS, MACHINES, TOOLS, DIE-MAKING AND WELDING METHODS

BY

F. HORNER

A RECOGNISED AUTHORITY ON SHEET-METAL WORK

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SHEET-METAL WORK

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CHAPTER 1

ART-METAL WORK

MAN'S highest forms of expression in metal go back into the mists of antiquity, from whence exquisite specimens of gold and silver work have survived. And the methods by which such creations are wrought remained much the same for thousands of years, excepting for some improvements in the tools and appliances employed, and the advent of machine processes, chiefly in the cheaper classes of art-metal work produced in copper, brass, tin, zinc, aluminium, bronze, iron, and stainless steel. The best kinds of work in the precious metals still demand handicraft by highly skilled men, who are also in many cases the designers. The cost of the metal and the constantly varying requirements of the object prevent the use of standard stock, to the same degree that it is possible with cheap material and repeated shapes. Consequently the goldsmith rolls out his sheets and strips in a hand mill to obtain the desired thickness, and draws wire to the necessary fineness through a draw-plate.

In the various classes of art-metal work, sheet or narrow strips alone may be used ; but hammered or cast portions may be incorporated, and very varied scope occurs for manipulation by means of hammers, stakes, punches, wood, lead and tin blocks, sandbags, anvils, vices, pliers, saws, drills, engraving tools, files, soldering irons, blowpipes, squares, callipers, compasses, and equipment for finishing and polishing. The processes may be roughly classified into formative and decorative, though the two are intermingled in very many examples.

Marking-out.—After an annealing, pickling, or flatting process, as may be necessary, the sheet has to be marked out, utilising variously a straight-edge, scriber, pencil, square, bevel, or compasses. The shape is determined by actual size, or estimated size if the sheet has to be changed into a bent or hollowed or raised form ; or the mode of development explained in Chapter 3 is followed. A steel scriber is the marking medium if the lines scratched can be subsequently removed ; but in other cases a pencil will be chosen as being harmless to the surface. Also, in order to avoid making a centre "pop" in the sheet from which a compass may be worked, a false centre should be used—a small disc slightly hollowed to rest firmly on the sheet, and having cross lines scribed on it and a centre "pop" in the intersection. Another use for a false centre is when a shape, as that of a bowl, has been raised, and a circle requires to be struck to show where to trim off the waste ; here a wooden plug put in the internal diameter of the work will afford a surface

for a striking centre. A height line, for trimming off or other guidance, may be marked around a raised object by the surface-plate method, scratching a line by means of the scribing-block. Templets are used for marking outlines of various kinds.

Cutting.—The practice adopted depends upon the thickness and hardness of the metal or alloy and the shape which has to be produced. Straight snips or shears are used for straight cuts or external curves, while curved shears will deal with internal curves, and serve to trim the rough edges from the rim of an article. Saws employed comprise hacksaws and backsaws for ordinary parting off or slitting in the thicker stock, fretsaws for removing internal sections of metal, or piercing (Fig. 1) for decorative effect, commencing at a small drilled hole. In thick material a circle or row of holes may be drilled, and a fine chisel be applied to sever the intervening bridges, but the results are not so neat as is the case with sawing.

Fig 1 — Craftsman saw-piercing a silver bowl (Mappin & Webb, Ltd.)

Bending.—This is the simplest of the formative operations, and is done with pliers, or by hand manipulation or malleting over a bar or stake. A hammer must not be applied. Testing can be done against a model or templet, or by trying the result upon the drawing of the object.

Folding.—To obtain corner shapes, square, hexagon, octagon, and other forms, the sheet has to be bent over a bar, by hand or using a mallet, a hammer being only permissible if sharp corners are required. Right-angled folds are obtained by gripping the sheet in a folding bar in the vice, this being a form of clamp which holds the sheet without damage. Sometimes metal or wood bars or blocks are employed to act as grips or guides while the folding is being done. Thick stock which cannot be folded into sharp angles must be filed with grooves across the intended locations, after which it can be readily turned up, and the corners silver-soldered on the inside.

Hollowing.—This is an action effected by mallet or hammer, whereby a shallow circular or elliptical bowl shape is evolved from the flat. The

procedure followed depends on the size. Very small sizes are worked in a steel doming block having a series of depressions, into which in succession, commencing with the larger ones, the sheet is driven by round-nose boxwood punches. Or a lead block may be used, a depression being made in it as necessary. Larger pieces are shaped by the help of a hollowed wood block, acting as support to the sheet whilst it is gradually worked by hammering with a ball-pane hammer. The wood does not constitute a die for exact contour, but supports the sheet while tilted to various inclinations. At first the angle is a very low one (Fig. 2), and hammer blows are directed a little in advance of the spot where the metal touches the wood, thus stretching it down quickly, and a succession of blows is given around the circle, then another series farther towards the centre, and so on. For large diameters a sand pad serves as support, and a round-nose (doming) mallet is employed. Owing to the yielding character of the pad, it is not so easy to produce a true shape free from twist. If the curvature has to be exact or fairly so, a thin templet cut to the profile may be used for checking purposes.

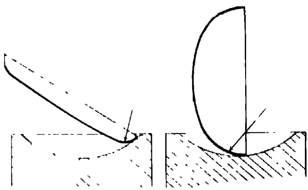


Fig 2.—Early and final stages in the process of hollowing.

Sinking.—When the central area of a piece is hollowed, the action is termed sinking, the process being applied in the manufacture of plates, salvers, and such-like objects. The method is to mark out the extent of the surface to be sunk, rest the disc or ellipse on a wood block, into which two nails have been driven to act as stops for locating the position of the piece so that the edge of the area to be sunk overhangs the block. A sinking hammer is directed in a series of blows to produce at first a shallow sinking (Fig. 3). The rim now requires flattening before going any farther, this being accomplished by reversing the work on to a wood block, and beating down the rim with a wood block and hammer. The base or hollowed portion is now flattened with a mallet with the piece turned over on the same wood block. After annealing, a further amount of hollowing is proceeded with, and the edge of the hollow is sharpened up by laying the plate with its rim on the wood block, the sunk part close up to the edge of the block, and malleting all around the rim.

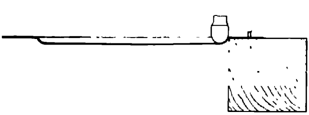


Fig 3.—The commencement of a sinking operation.

Stretching.—The diameter of a piece may be increased by the process called stretching—hammering the subject upon an anvil or stake to thin

the metal and cause it to spread and gradually change the form. A splayed contour may be thus evolved for a vase, pot, or jug. Stretching is performed from the outside or the inside, the latter being chiefly applicable to shallow examples. A hammer having a slightly convex face is necessary for external stretching, and the stake is of suitable form (Fig. 4) to support the shell being handled. By a succession of overlapping blows delivered around the circle and slowly moving up from the edge, the metal is coerced from a parallel to a cone shape, or a parabolic curve. For internal stretching a stake with curved surface is required, and a collet hammer, possessing a curved face as nearly as possible appropriate to the diameter of the piece, is essential.

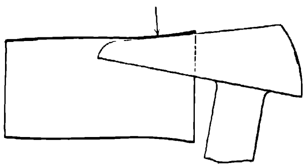


Fig. 4 —Mode of stretching

Contracting.—The opposite process from that described in the previous paragraph consists of reduction in diameter of a cylindrical shape, which is hammered all around in concentric or spiral courses upon a stake until the desired portion has been made smaller by the compression of the metal. The stake (Fig. 5) needs to be rather long so as to support the work adequately to prevent it from bulging up, and the nose of the stake is finished to the required curve to which the contracted part must be made. A canister stake or the end of a round bar serves for support when contracting a turned-down rim, and a stake with hollowed nose must be used for concave contracting, such as when reducing the waist of a collar or foot.

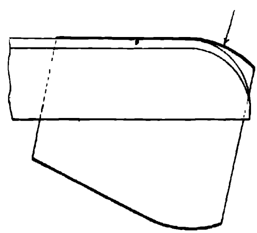


Fig. 5 —Contracting

Raising.—This is the equivalent of spinning, but executed at a slower rate. The metal is coerced into a shaped body from the flat disc by resting it upon a stake and hammering from the outside. In this respect it differs from hollowing, which has the disadvantage of causing thinning, and may be objectionable therefore for the taller articles. Raising can be performed upon a ball or mushroom stake, using a wedge-nose mallet having a rounded edge, which enables the disc to be contracted around the stake by a series of blows a little distance ahead of the spot where the sheet touches the stake (Fig. 6). Annealing will, as usual, be necessary between reductions. Another method is that of resting the piece at a low angle upon the curved nose of a stake, and hammering a series of blows which result in the formation of an annular indentation, further courses of blows carrying this indentation progressively up to the edge. The ow raised form which has been obtained at first gradually alters into a

pan shape and eventually into a pot or vase type as requisite, the angle at which the work is held on the stake being increased from time to time.

A class of raising performed from the inside is adopted in certain instances, such as to raise decorative bosses, etc., or to make a convex profile in the longitudinal direction, which cannot be accomplished upon a flat stake. A snarling iron is the tool utilised (Fig. 7), gripped in the vice, and struck with a hammer on a spot a short distance along the shank; the rebound causes the end to strike against the work which is held over the nose. As a preparation for raising a convex body by means of the snarling iron, a pot can be formed into a set of flats upon the raising stake, these being afterwards merged into the curve on the iron. A stage of working from raising is panelling, or making flats on a convex shell. After the latter has been raised it is placed over a hardwood block or stake, having a surface corresponding to one face of the object, and the latter is beaten with the mallet, treatment being repeated around the periphery until the hexagon, octagon, or other form has been produced. Another process connected with raising is caulking, or thickening the edges of bowls and like articles. A little is done after each stage of raising, while the work is stiff enough to resist buckling, hammering the edge with blows directed in line with the metal (see also Fig. 12).

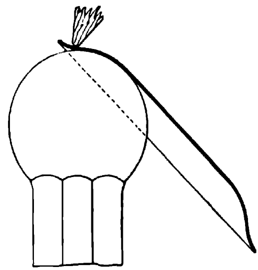


Fig. 6.—An early stage in raising.

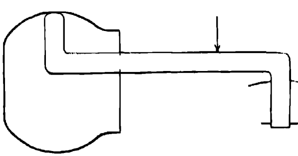


Fig. 7.—The action of the snarling iron.

Planishing.—All the results of hammering and malleting must be removed to leave a smooth highly finished surface free from irregularities. During the manipulations care must have been observed to reduce the risks of scratches and indentations being made. Thus, hammers and stakes (Fig. 8) must possess smooth polished surfaces, and sharp edges should be rounded off; moreover, indentations and scratches may be produced by unsuitable vice clamps, or a bench or other surface not kept clean from particles of metal. Assuming, however, that the work is in good condition, the operation of planishing consists of hammering all over with a suitable hammer while the piece is supported upon a stake. This levels down the surface, trues it, and closes the grain. The curvature of the stake has to be rather less than that of the object. Very light blows are given, and in successively changing spots, the result being the formation of a multitude of facets merging together. In order to avoid the production

of scars from the hammer, flat work must be planished by a hammer with very slightly convex face and rounded corners, but convex metal is done by a flat-pane hammer. Avoidance of stretching and distortion are the chief precautions essential, either being likely if an unsuitable stake or stakes are employed, and the hammering is too violent or localised and irregular in sequence. Difficult specimens, for which a suitable stake is not available, or cannot be applied because of the narrow mouth of the object, can be filled with a composition of pitch and plaster of Paris melted and poured in. When this has set, the piece is rested upon a sand pad for planishing, the composition being subsequently melted out. Lead is employed in certain cases as an alternative, chiefly for small examples.

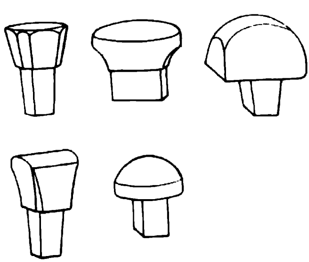


Fig. 8.—Some of the stakes used in planishing

Finishing of Edges.—One of the final formative processes is that of dealing with edges so that they shall have a better appearance or be stronger than when left plain. The caulking already described may be done, or the sheet can be folded over while held in grips as explained previously, or malleted upon a stake and finally closed into a neat roll. In real wiring, the metal has first to be partly folded, then the wire inserted. The fold is then closed around it by means of a grooving tool, having a flat face and half-round groove, which is struck with the hammer to coerce the metal neatly around the wire. Sometimes malleting has to be done instead, completion in either instance being effected by a setting-down tool, a sort of blunt-edged chisel which is driven down to close the metal tightly and neatly. Another mode of strengthening and decorating an edge is to solder a round or other section wire, or a drawn moulding thereto.

Chasing.—Chasing or embossing refers to work usually done on the front of a piece to produce ornamentation, but repoussé is a fine class of work executed first from the back and then from the front. A great variety of punches having diverse patterns upon them is employed, and being selected according to the size and arrangement of the design, many beautiful patterns are produced. Some kinds of embossing are performed while the article rests on a lead block or sand-pad, but generally a mixture of pitch, plaster of Paris, and oil or tallow forms the bed. It takes time to prepare, to set the work, and clean it off afterwards, but nothing else is so good. The compound has to be poured on a convenient base, such as a thick wooden slab, and after a suitable bed has been prepared of it, the work is greased, pitch poured on it and on the bed, the object then being pressed carefully down so as to squeeze out all air bubbles. The surface to be

embossed has to be cleaned, and the design traced on it direct, or through a tracing stuck on with wax, and worked with the various punches. In repoussé the effect is to leave a roughly embossed relief, which is next worked on from the front to sharpen and perfect the design. High relief is produced by driving the ground down from the front and the form out from the back. Removal for annealing is necessary to avoid risk of the metal cracking.

Engraving.—Decoration by the engraving process applies to certain kinds of art-metal work, and is executed by means of a variety of fine, sharply bevelled tools having different shapes which are thrust by the hand, giving thin vee cuts, curved, tapered, square, half-round, and other profiles. Heavy work, such as that performed on memorial brasses for inscriptions, is done with a chisel and chaser's hammer, the chisel being held at an angle of about 45°. Support for articles done by the hand gravers depends on size. A small specimen may be stuck on melted resin on the end of a stick, while a larger piece, such as a cup, will be filled with pitch and supported as for chasing. For enamelling, engraving has also to be effected, but the cutting is deeper so as to hold the enamel firmly, and in addition the floor may be roughed over or the edges of the pattern be undercut if the roughening would be objectionable, as when using translucent enamels.

Fig. 9.—Electro-gilding the inside of a rose-bowl at Mappin & Webb's

Etching.—Designs and names are etched in brass, steel, and other plates by acid, the surface being coated evenly with wax, the lines of the pattern scratched through with a sharp steel tool, and acid poured on in sufficient amount to fill the recesses. For brass, nitric acid is used, or a compound of nitric acid, water, and potassium chlorate. Steel is etched by a mixture of nitric acid and water, or hydrochloric acid, water, and potassium chlorate.

Finishing Processes.—These cover a considerable range, comprising some amount of filing and trimming, testing, corrections for distortion produced by the hammering and other operations, and finally cleaning up, smoothing, and polishing. Small files are utilised in connection with some of the forming actions, as chasing, but still more for cleaning up, removing rough edges, finishing soldered joints, fitting clasps and hinges, etc.

The amount of cleaning up necessary on a piece of hammered or raised work partly depends on the care exercised during manipulation, and before any polishing can be done all the scratches, indentations, and

other blemishes must be eradicated. Dead-smooth files and Water-of-Ayr stone are employed, finishing with fine emery paper. A weak sulphuric-acid pickle serves to remove the remains of flux and other foreign matter, and a boiling in soda water and washing in hot soapy water makes the surfaces ready for the final treatments. A preliminary surface preparation is effected by means of fine pumice powder and raw linseed oil, or crocus powder and machine oil. After securing a very smooth but dull lustre, the piece is washed in hot soapy water. Finally, a metal polish imparts the final brilliancy, the kind used depending partly on the class of material; for instance, there are polishes specially suited for silver. Rouge on chamois leather is the last medium. Some kinds of work are coloured by heating or the application of a powder or solution, while plating (Fig. 9) and lacquering form other methods of giving a finish.

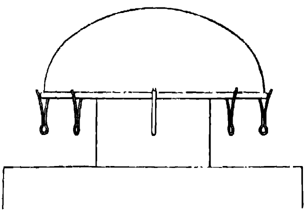


Fig. 10—Rim secured by spring clips, ready for soldering

Soldering.—Some amount of ingenuity has to be exercised in arranging parts for soldering, many specimens being awkward to hold accurately in position, and a good deal of clipping and wiring is needed for retention purposes. Special holding appliances simplify jointing.

Fixing the Work for Soldering.—The support of a fireclay slab is requisite for a great many soldering operations, and often a vertical slab stands at the rear to afford further support, or control the heat, much of which would otherwise be wasted. Heat may also be lost if the base of the object makes too much contact with the horizontal slab, therefore bits of fireclay must be placed underneath. Sometimes two or more fireclay blocks act as locating media for keeping simple units in place.

Fig. 11.—Hard-soldering a mount to a silver coffee-pot at Mappin & Webb's.

PROCESSES AT THE WORKS OF JAMES DIXON & SONS, LTD., SHEFFIELD

Soldering the mount on a nickel-silver meat-dish, rotated on a turntable Soldering and making up a teapot Hammering salvers and trays to harden the pores and make the tray rigid and set Spinning a teapot body Chasing a silver article which has been filled with pitch

Fig 13 — Hand-chasing the design on a silver teapot. (Adie Bros Ltd).

Fig. 14 -A fine example of a large silver bowl in Paul Lamerie style It measures 16 in long by 12 in wide, and is hand wrought throughout. (Adie Bros, Ltd).

CHAPTER 2

SHEARING MACHINES

Importance of the Machine.—The ease with which sheet-metal can be cut up by means of the shearing process accounts for the many types of shearing machines, capable of making straight, bevel, contoured, irregular, and circular cuts. It is practically the universal method of obtaining shapes, with the exception of nibbling or sawing, both of which have relatively limited application. Blanking with dies is a class of shearing used on repetition jobs. There are many systems of controlling the operation of shear blades in order to obtain the great variety of outlines necessary, but the use of a guide or gauge strip is the most usual method. High-class and rigid construction is essential for any kind of shear, otherwise a clean cut will not be made; the sheet may be stressed or distorted, and the blade will not retain its edge for long. Accurate grinding of the blade is also imperative, and it must not be used after dullness has developed. There is no difference in the principle of shearing thicker plate, except that greater strength and power are required.

GUILLOTINE-TYPE MACHINES

Principle of Guillotine Shearing.—The commonest way of parting, by a guillotine blade, entails careful setting to ensure clean results.

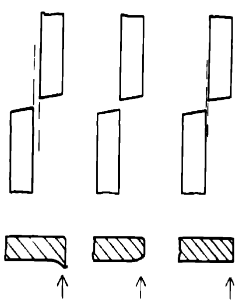


Fig. 15.—Showing the results of incorrect and correct setting of shear blades.

The diagram (Fig. 15) explains incorrect and correct setting, the latter giving the maximum endurance to the cutting edges, with minimum power expenditure, and no unnecessary stress on the machine parts. As regards

shearing action, the effect of excessive clearance between the blades is that a burr forms on the underside of the sheet, as seen in the first view. With no clearance, overstrain is caused, the edge of the sheet becomes flattened on the underside, the second illustration showing this defect. In the third diagram is seen a perfect parting. The clearances in parts of the inch, recommended by the makers of the Rhodes shears, are as follows

Inches	Clearance	
	Brass, etc	Steel, etc
015	—	·0005
032	0015	·0018
065	0020	0025
100	0022	·0030
125	0030	0040
250	0055	·0070

The clearance is tested by a feeler, adjustment being made by means of screws.

Types of Guillotine Shearing Machines.—The varied demands of small and large works and different classes of manufacture involve the services of several different designs, small and large, simple and complex, and with various modes of driving. The lightest style, for small workshops, is actuated by treadle leaving the operator's hands free to manage the sheets. Front, back, and side gauges are fitted, and it is most convenient if the back gauge has its adjustment effected by a handle from the front. The gauges can be set straight or angularly. The machines are built in standard sizes, the blades being about $\frac{1}{2}$ inch longer than maximum size of job for the machine, thus: $12\frac{1}{2}$, $20\frac{1}{2}$, $24\frac{1}{2}$, $30\frac{1}{2}$, $36\frac{1}{2}$, $42\frac{1}{2}$, $48\frac{1}{2}$ inches. The shears can be supplied with blades for cutting curves of single-sweep or waved style. To obtain greater power than is possible by the use of the direct-lever mechanism of the treadle, a hand-rotated flywheel and train of gearing is employed in some machines, cranks connecting the last motion shaft to the slide, the handwheel being placed low down at the rear, or higher, on a shaft running on overhead bearings. Steel sheets up to $\frac{1}{16}$ inch thick can be cut on this type of machine.

Power-driven Guillotine Shears.—For still greater power and rapidity of output, moderate-sized machines of similar form are driven by belt-flywheel direct on the crankshaft, or through a pinion. The operating clutch is controlled by treadle, which allows a key to engage in the gear-wheel. On depressing the treadle the beam descends and returns to the highest point, then the sliding key is automatically withdrawn. The machine can thus only make one stroke, even if the treadle is inadvertently still kept down. By releasing this trip motion the machine will work

continuously—a necessity in some cases. A spring or cam-actuated hold-down apparatus may be included to grip the sheet firmly before cutting. Shears of this design are constructed up to about 8 feet capacity. In continuous working a speed of 65 to 70 cuts per minute can be attained on sheet up to about 14 s.w.g., but the heavier models dealing with plate to ¼ inch thickness run at about 20 strokes per minute. Fig. 16 shows the arrangement of the spring cramp for Taylor & Challen underdrive shears, and the disposition of the back gauge. Special waved-edge blades are fitted to machines for shearing corrugated iron. A specially

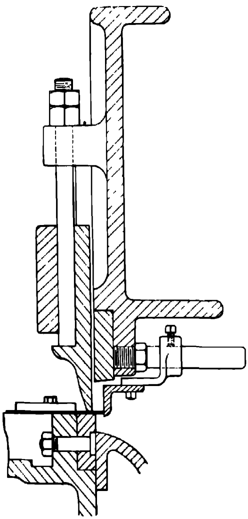


Fig. 16.—Arrangement of cramp and back gauge on Taylor & Challen guillotine shears.

Fig. 17.—Shearing machine for cross-cutting strips

powerful style of machine is built with cam-actuated slide, the blades not exceeding about 30 inches long, the maximum thickness of cut being $\frac{3}{16}$ inch. This cuts into strips sheet brass, alloys, or steel, for spoon and fork blanks, hinges, etc. Another single-purpose design shear (Fig. 17) with a narrow blade will cross-cut such strips, an adjustable gauge being located behind the blade for determining the length. A specialised type of guillotine is built having veed blades for the purpose of cutting serrations in the edges of corrugated sheet.

Overhead-drive Machines.—A far greater number of guillotines are

constructed with the shafting and gears above the blade slide. This avoids the inconvenience and encumbrance of having the transmission near the floor, and is the only practicable way for the larger sizes of machine. Single-crank and double-crank types, the former only for a few narrow kinds of machines, occur in many variations as regards arrangements of drives, tables, cramps, and special setting or feeding devices. An advantage of the overhead drive is that the couplings of the crankshaft rods are in compression, instead of in tension, as in under-drives; consequently, the bolts which attach the caps to the couplings are not so liable to fatigue and overstrain.

Driving systems comprise direct belt-pulley transmission on to the crankshaft, also single- and double-gear connection, the latter being used only for thick sheet or plate, and for the "pack" shears employed in rolling mills to cut stacks of sheets. Fast-and-loose pulley belting arrangements have been largely superseded by mounting an electric motor at the top or rear of the frame and using multiple vee-belts of the rubberised type to connect the motor pulley to the flywheel rim (Fig. 18). Safety guards encircle the gears, and in one maker's practice the back shaft is encased in a steel tube, adding to the rigidity of the framing as well as protecting the operator from danger. The larger machines cut to about 13 feet 6 inches wide. On Rhodes' high-speed shears, a twin-bolt safety clutch is fitted, which renders it unnecessary to use brake pressure, or to balance the beam. One bolt in the clutch drives and the other controls, the bolts being of semi-spherical shape, turning in seatings.

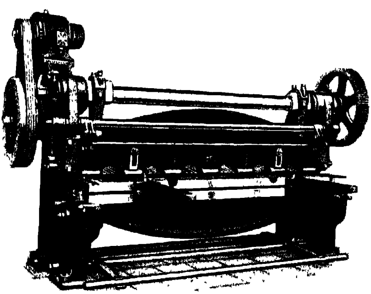


Fig 18.—Rhodes high-speed guillotine shearing machine

Frames and Tables.—In some machines deep-gap frames are cast so that the sheet can be passed beyond the blades for a considerable distance. Thus wide strips can be cut from sheets of unlimited lengths, a gap as deep as 2 feet being given on machines of capacity ranging from 4 feet to 8 feet size. Again, for dealing with very wide sheet, a special squaring guide may be located on the left side of machines consisting of angle iron on a girder extending outward for the desired distance. Anti-scratch

devices are provided when it is essential to prevent marking of highly polished sheet, the table and hold-down plate being covered with felt, fibre, or leather ; or rollers are arranged on the table, two of fixed height in front of the blades, and a pair fore and aft, to rise and fall slightly with the movement of the beam. To cut large numbers of strips from sheet, an automatic feed table is attached, the sheet being held in grippers that move forward in time with the blade reciprocations. On 36-inch × $\frac{1}{8}$-inch sheet 90 strips can be cut in a minute.

Automatic Cramps.—Either springs or cams actuate the hold-down cramp, to prevent the sheet from slipping. For reasons of safety, the openings in a hold-down cramp should be filled in with expanded-metal trellising, thus enabling the blade to be seen. The cramp acts as a finger guard, although sometimes a trellis finger guard is attached in addition. The time and trouble necessary to remove and replace a cramp when the blades have to be detached for regrinding are saved in the Rhodes' swivel cramp, which is slewed upwards for this purpose. A specially powerful positively operated cramp has to be applied to pack shears, in order to flatten the pack on the table before the shearing takes place (Fig. 19).

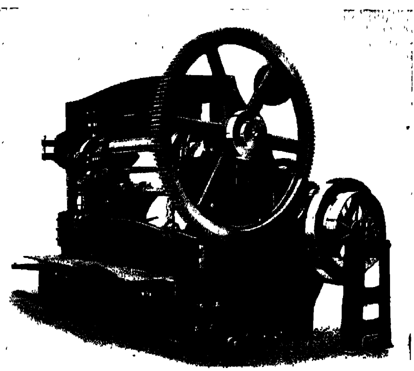


Fig 19.—Sheets held down by powerful cramp on Rhodes' pack shears

Combined Shearing and Planing Machine.—An unusual combination design of a modified guillotine character has an ordinary straight bottom blade (built up in sections for convenience of regrinding and replacement), but a top blade of circular shape which is pulled along through the sheet by a chain. After shearing the sheet at 90°, a slight readjustment enables the edge to be trimmed to a welding angle.

ROTARY BLADE MACHINES

Slitting Shears.—The slitting down of sheets is more often done by hand shears, or hand-operated shearing machines, than it is by power-driven guillotine types. The reason is that the rotary-blade shearing machines are able to do the work more conveniently. A pulley-and-gear

driven slitter is made with rather short blades, and a gap about 2 feet deep, the sheet being fed across a plain table.

Rotary Shearing Machines.—These constitute a large and diversified group utilised for straight, circular, and contour cutting, also for trimming stampings, the principle in every case being the same, two circular bevel-edged wheels parting the sheet. For slitting into narrow strips the cutting edges are multiplied. It is essential that the cutters should be of good diameter, so as to secure a grip on the sheet at once, and also to provide stiff bearing support as close as possible to the disks. For thick sheet or plate shearing, an outboard support is sometimes added for the lower cutter-spindle to eliminate risk of springing (Fig. 20).

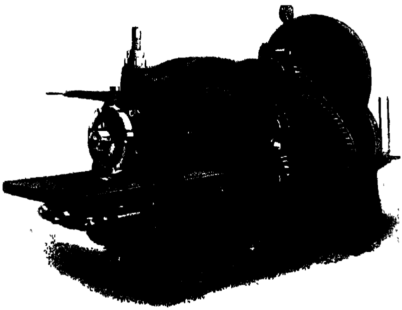


Fig. 20.—Rotary shearing machine for thick metal.

Hand-driven Machines.—A simple type is made with a handled fly-wheel driving the lower cutter spindle, with pinion connection to the upper spindle. The latter runs in a long tube which is pivoted close to the pinion, so that by turning a handwheel and screw, the tube can be pressed down to bring the upper cutter into the required position. A long, planed, movable guide can be set to cut strips from 1 inch to 12 inches wide, and up to about 18 s.w.g. in steel.

Belt-driven Shears.—These occur in a number of styles, to go on the bench or on a pedestal. The simplest design is very similar to that just described, but of more massive construction. The drive takes place direct from the fast pulley to one of the pinions, or a hand-lever clutch is fitted to start and stop the cutters instantaneously. Two different methods of adjusting the spindles are to be noticed. One style has the upper cutter spindle mounted in a swivel bearing at the driving end, and close to the cutter there is a bearing box which can be raised or lowered by means of handwheel and screw. Another arrangement has bearing boxes at both ends of the shafts, adjusted vertically by screws. A special form of pinion drive is adopted here to allow for considerable reduction in the diameter of the cutters from regrinding, the belt pulley rotating a pair of pinions on shafts alongside the cutter spindles, the pinions on these shafts meshing with the other pinions on the cutter spindles.

Thus an alteration in the up or down position of the cutters does not interfere with the operation of the drive.

Motor-driven Machines.—These tend to displace the pulley types, the motor being placed on the top of the frame, and driving the cutter-spindle pinions through double reduction gearing. A hand-lever clutch, as previously mentioned, gives instant control, this being of special advantage when cutting curves. Cutter diameters vary according to the thickness of sheet to be sheared, though this is only an approximate rule, as large diameters gives greater facility for quick operation; for example, taking two listed machines, both having capacity up to ¼ inch, one carries 8½-inch, the other 12-inch cutters.

Gauges.—The mode of fitting these depends on the shape of the framing. If the frame is a narrow casting, the gauge is attached by bolt in a T-slot at the side, or two T-slotted bars are fastened, one on each side, the gauge spanning over their tops. This idea develops into a table in other examples, with clamping slots on the top, close to the edges. Some machines have two cylindrical bars acting as guideways, with the gauge clamped by set screws after sliding along to the required setting. Or more convenient adjustment is effected through the medium of a handwheel actuating gears and twin screws which ensure accurate squaring.

Special Slitting Shears.—Modifications of the rotary shears are built for special purposes. A sliding table on trackways in front of the machine will feed long sheets for rapid output. A drum-slitter cuts through the bodies of old drums, which rest on a horn while the cutter feeds along through the metal. For cutting out the ends of drums, roller supports (Fig. 21) take the drum, which revolves to perform the severing operation.

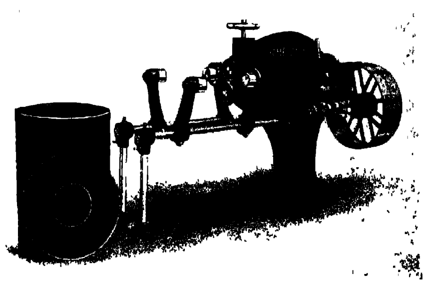


Fig. 21.—Drum-end slitter which cuts out the ends of disused drums.

The parallel shearing machine trims the edges of strips and makes them parallel. Two different systems are followed, one with quick regulation for narrow or wide strips, which is done by placing duplicated cutter-heads on a bed, along which their spacing apart can be adjusted by a handwheel, to a maximum distance of 18 inches. A more usual practice is that of putting the upper and lower pairs of cutters on long spindles, their pitch being determined by

the distance-pieces, placed between them. A table has adjustable angle-plate guides that keep the strip in proper position for feeding through, and a friction-driven winding-drum is provided to coil the sheared metal. On the larger machines feeding-out rolls are situated on the delivery side and take control of strips and scrap edges. For the safe and accurate cross-cutting of strips, such as are used for box-making, a cross-slide is employed, operated by a handwheel. By placing more cutters along the spindles, a sheet may be slit into a number of narrow strips.

Gang Slitters.—The last-named principle is met with in a variety of machines which mount a gang of cutters on the spindles, as many as a

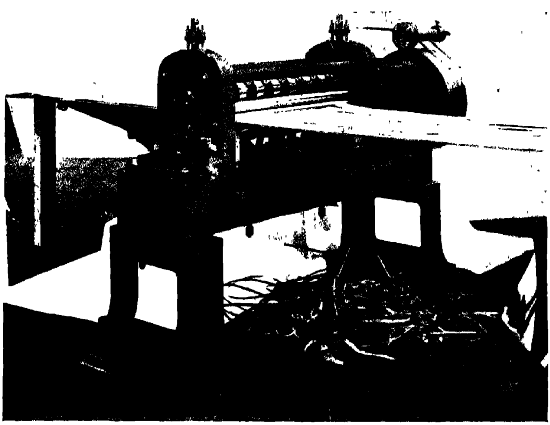


Fig. 22 — Gang-slitting machine having independently adjustable cutters

dozen disks being spaced with distance collars, or screwed mountings are employed to give independent adjustment to each cutter (Fig. 22). Automatic feeding-out rolls take charge of the strips and scrap, as in the duplex-cutter type previously mentioned. A portable electric grinding attachment enables the cutters to be sharpened without having to remove them from the spindles. This grinding machine, which requires ¼ h.p. for its operation, is fitted by a screw-adjusted slide to a cylindrical stem which may be moved vertically and clamped in a bracket. The latter bolts to a pair of T-slots running along the table (Fig. 23), and the upper and lower sets of cutters can thus be sharpened on their faces without having to remove the feed rolls. The compound slide gives complete control over the wheel position. The cutters must not be ground less in diameter.

To cut very narrow strips—for instance, in one case 28 strips from a piece $4\frac{1}{2}$ inches wide by 12 s.w.g.—accurate controlling mechanism has to be incorporated in the machine to obtain the narrow units parallel and without twist (Fig. 24). Running the cutters at 18 r.p.m., the material is slit at a speed of 40 feet per minute. A powerful feed mechanism is furnished in the case of one type of machine which slits $\frac{1}{8}$-inch steel plate. Serrated rolls engage with the edges of the sheet and force it forward, passing it through steel guide plates in front of the cutters.

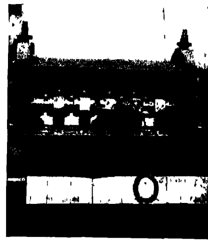


Fig. 23.—Portable electric grinder for sharpening the cutters

Circle Shears.—Some of the rotary machines can be equipped with an attachment consisting of a slidable bracket and pin to rotate the sheet

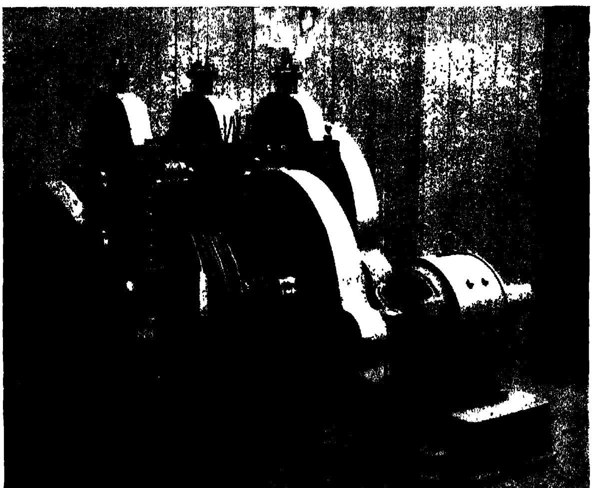


Fig. 24.—Slitting machine for very narrow strips (Taylor & Challen, Ltd.)

by the action of the cutters, but generally a regular circle-shear is utilised, having a substantial bed or table with an adjustable bow casting and pressure-pad in the top of the bow (Fig. 25). Many variations occur

according to size, and different devices to yield rapidity of manipulation are employed. The tinner's circle-cutter sometimes holds the sheet between point centres, or a circular pad below and centre above, but all the larger machines grip between disks, the upper spindle being tightened by a screw or cam action.

In most types the saddle which supports the bow is adjusted along the bed by handwheel and screw, or handwheel, rack, and pinion. For very large diameters, attaining 6 feet, the bow principle is not used, but a fixed overhead beam reaches from the top of the shearing-machine frame along to a bracket bolted to the extreme end of the bed, and the large disks, between which the sheet is clamped, are carried on spindles in brackets adjustable along the bed and the beam, with screw tightening in the upper bracket. Another system for large sizes is that of making the bow in closed form instead of open at one end. The pressure is either imparted by handwheel and screw direct, or a long lever is pivoted a little way from the central axis, and when forced down by a handled screw at the extremity, effects the tightening of the pressure spindle and pad. The lever being counterweighted, automatically relieves the pressure as the handle is released.

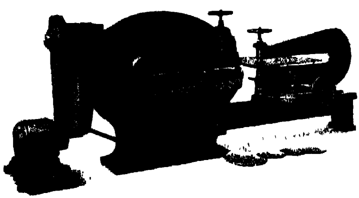


Fig. 25 – Circle-cutting machine of 4-feet capacity

Self-centring Guide.—To facilitate setting the square sheets truly and quickly, the Rhodes' self-centring guide or table can be fitted. The usual method of centring is by means of a small finger, against which one side of the sheet is pressed, the cutters being used as a guide against which the other side is set. This puts a slight flat at one point of the circle. The self-centring guide comprises a table (Fig. 25), with adjustable stops against which the two sides of the sheet can be instantly set. When the bow is moved into the cutting position the guide table and stops automatically fall below the sheet.

Offset Bow.—Some of the Taylor & Challen machines are constructed with a bow which at first is swung out of centre, so that the cutters commence at a point outside the true circle. As they draw in the metal the bow swings up to a stop in the centre position, and a true circle is the result, without leaving a flat at the starting point. In one machine possessing this feature and which has been specially designed for trimming the flanges on bowls, the bow has a deep gap to the cramp, to accommodate these articles, and the cramp has a long stroke. It

should be mentioned that in power-driven circle-shears the control of the cutter drive is by pedal to leave the hands free for manipulating the work.

Ring Shears.—To cut washers and large rings such as are required for electrical purposes, a simple centring-spindle mounting only is necessary. The sheet has to have a small hole pierced in the centre, to fit on to the centring spindle of the bracket, which is set along the bed by handwheel and screw for the different diameters. The ordinary style of bow and pad grip may also be utilised for this service, as well as for cutting circular

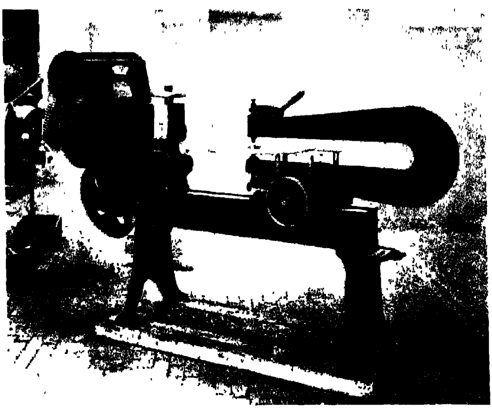


Fig. 26.—Circle-shearing machine for cutting rings.

holes in sheets. Fig. 26 shows a machine, with inclined spindle, specially for this class of work.

Rotary Shears for Varied Cutting.—This class of machine carries two bevelled cutters on inclined spindles, the sheet sliding over a table through which the lower disk projects slightly. For trimming stampings the table is removed. Any shape can be cut—straight, zigzag, curved, irregular, or scroll. Small hand-driven shears are built to cut sheet up to about 18 s.w.g., while heavy power-driver
steel. With a deep gap, which may reach 5 feet
must be used on somewhat thinner stock, beca
The Oliver "Quickwork" machines are mo
with three speed changes (9, 15, 22 feet per m
with hand drive for cutting very small radii,
starts and stops the machine without cutt
standard cutter diameter is 2 inches, with whi
can be cut in 14 s.w.g. is 1¼ inches, although s

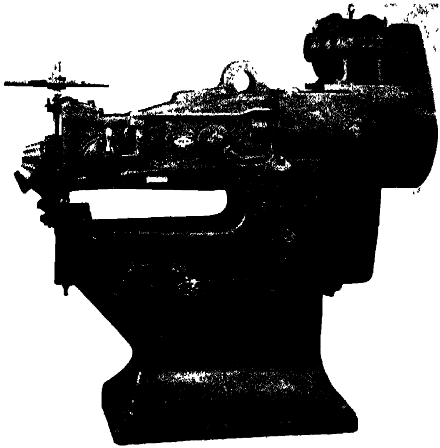


Fig. 27 – Rotary shearing machine which cuts any shape in sheets

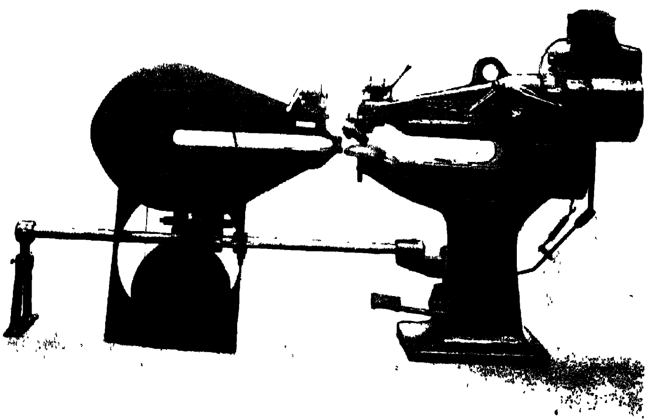


Fig. 28 – Circle-shearing attachment for the "Quickwork" shearing machine.

lighter gauges of metal. A special shape of machine deals with the trimming of stampings, when there is a large amount of this to do. It is a compact frame type, resembling a portable hydraulic riveter in appearance, having a motor drive, and being either attached to an overhead beam, or to the face of a steel column. The U-shaped horn, at the extremity of which the lower cutter projects, gives complete freedom to manipulate the stampings.

An automatic circle-cutting attachment can be used in connection with the ordinary machines, this being seen in Fig. 28, in which the throat is 30 inches deep, and the attachment will shear circles 6 feet in diameter.

Gray's Sheet-metal Cutter.—A novel principle is adopted in this machine, which will shear to any outline. The sheet is held between upper and lower rollers, which feed it forward intermittently. The cutting members consist of a vertical reciprocating knife and a horizontal stationary cutter, the latter acting as a shearing-bar. The vertical knife reciprocates rapidly past the lower cutter, producing a continual chipping action, the rate of feed being from 10 inches to 80 inches per minute, according to the kind of material and its thickness.

Sheet-metal Thicknesses.—In addition to the foregoing, mention may be made of the various types of heavy shearing machines which are so extensively employed in the shipyards, boiler shops, and structural engineering establishments. In these volumes we are, of course, using the term sheet-metal work as applied only to relatively thin materials, materials the thickness of which is usually measured on the British Standard Wire Gauge (s.w.g.) for which 1 s.w.g. is actually 300 mils or ·3 inch in thickness. The thickness of the sheet decreases with the s.w.g. figure, so that, for example, 10 s.w.g. has a thickness of 128 mils, *i.e.* ·128 inch, which is approximately $\frac{1}{8}$ inch, while the highest s.w.g. number which is usually to be found in most lists, *i.e.* 40 s.w.g., has a thickness of only 4·8 mils, *i.e.* ·0048 inch, which is but little more than $\frac{1}{200}$ inch. Actually a 50 s.w.g. having a thickness of 1 mil is occasionally met with. At the other extreme of the s.w.g. table will be found values lower than 1 s.w.g., and these are expressed by the use of cyphers so that 0 s.w.g. plate is 324 mils or ·324 inch in thickness, 00 s.w.g. is 348 mils or ·348 inch, and so on, increasing the number of noughts up to the thickest plate expressed on this gauge, which is 0000000 s.w.g. having a thickness of 500 mils or ·5 inch, which is, of course, $\frac{1}{2}$ inch. It may seem rather remarkable that the standard method of expressing the thickness of metal sheets or plates should be by means of a "standard wire gauge," but that happens to be the general usage of the sheet-metal industry.

The shipbuilder, boiler-maker, and structural engineer deal with plates, generally made of steel, the thickness of which is often far in excess of the figures given in the table of s.w.g. sizes, and the gauge used is expressed in terms of pounds per superficial foot. Hence, as a sheet of

mild steel 1 square foot in area and $\frac{1}{40}$ inch in thickness weighs 1 lb., what is termed a 30-lb. plate, *i.e.* a plate weighing 30 lb. per square foot, will have a thickness of $\frac{30}{40}$ inch, or $\frac{3}{4}$ inch.

Heavy Shearing Machines.—It is of interest to note that steel plates of any thickness up to and exceeding 1 inch, and of a superficial area up to the maximum size usually manufactured, can be readily cut to any desired shape and size by means of heavy shearing machines having a single reciprocating blade acting on the same principle as the guillotine shears described above, except that a far greater power is required to operate them, while the construction is necessarily far more massive throughout, particularly in view of the fact that in the largest sizes the machine can handle single plates as much as 50 feet long by 9 feet wide. The flanges of the angle bars, tee bars, channels, etc., which are used in conjunction with these plates usually have a thickness approximating to that of the plates themselves, and while some of these standard rolled sections are sometimes cut to length on heavy shearing machines provided with beds of special shape, the saw is the more usual type of machine employed, particularly for girder sections.

CHAPTER 3

BENDING AND FORMING MACHINES

Formative Operations.—In the methods of obtaining the innumerable shapes required, sheet-metal working is fundamentally different from that practised in the machine shop. Cutting processes, as we have seen in preceding chapters, are mainly performed in order to change the plan outline of strips or sheets. To evolve angular, curved, or contoured forms or envelopes, pipes, troughs, corrugated objects, flanged parts in sheet-metal as well as in wire articles, bending is the system which is employed. There is so much diversity in requirements that an extensive class of tools, appliances, hand- and power-actuated machines, each serving in numerous ways, on a small or large scale of production, are employed to change the original form of the material. Some of the bending and forming is done by hand control, and the results mostly depend upon the skill of the worker; but in the main the use of rolls, formers, dies, and mandrels enables accuracy to be ensured by any machine operator. Sometimes the action consists in simple pressure in a direct line; in other cases a rolling or turning motion becomes necessary. One setting only, or successive ones, depending on the shape required or whether multiple bends are wanted, may be made. The difficulty of obtaining sharp and parallel bends in heavy-gauge metal has to be surmounted by building very strong presses, free from risks of flexure or twisting. In heavy machines, tie-bolts or bars are fitted to the side frames (as they are in some other sorts of presses) to further enhance rigidity.

The tinsmith's folders and angle benders are only representative of a comparatively small class of machines, of somewhat similar type; beyond these occur a varied range of very diverse styles, actuated by hand, foot, or power, for ordinary or special functions, many of the latter being single-purpose designs, often for constant use on one size of work. The biggest presses deal with sheet ¼ inch thick by 10 feet wide, and wider if the sheet is a little thinner. Some of the tinsmith's little machines, as an example those for beading, are represented in larger sizes for general sheet-metal working.

Bending-rolls.—The increased capacity and power requisite to bend sheets of iron, steel, copper, etc., are supplied by a choice of hand- or power-driven bending-rolls differing in arrangements of gearing and methods of mounting and adjusting the rolls. Quickness of operation is always essential, and one method of saving time is to avoid the necessity for

adjusting the curving roller by separate screws at each end, employing instead a lever or handwheel, so that the change can be effected in half the time. The slipping off of tubes demands some means of freeing, and this is done either by moving the top roll endwise, or by tipping one end up, or swinging it sideways. One small machine for making pipes embodies automatic release, so when the cap of the bearing is swung upwards, a spring at the tail end of the roll tilts the latter up. In some larger machines the roll is extended beyond the gear, and a pad in a supplementary housing is pressed down by a screw. Thus the roll is held firmly, whilst the bearing at the far end is swung out of the way.

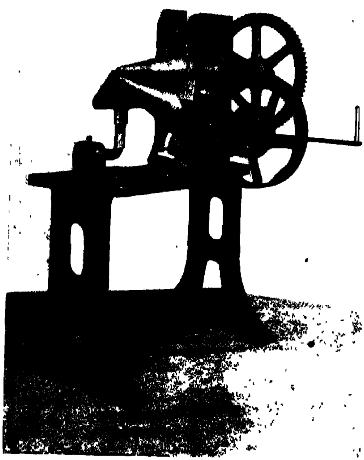


Fig. 29.—Cone-rolling machine. (Walter Frost and Co. Ltd.)

Size of rollers range from less than a foot in length by about $\frac{5}{8}$ inch diameter to 6 feet long, for ordinary purposes. The diameter may have to be small, even in the length specified, when the machine makes pipes. One of this kind has $2\frac{5}{8}$-inch rollers, and the bottom one is supported in the centre by a roller cradle in order to prevent flexing. For high-speed production a special pipe-forming machine is constructed, with two rolls: the lower one is selected to suit the pipe size, and has a groove in it to receive the folded edge of the sheet. When this edge has been hooked into the groove, the treadle is depressed and a revolution takes place; then the machine stops automatically, and the roller can be swung out for removal of the pipe. Sizes from $2\frac{1}{2}$ inches to 5 inches × 3 feet long are produced, one of the particular applications being that of manufacturing motor-car silencer tubes. In one specimen of small rolling machine, the rolls are coated with rubber, so that, if the sheet has to be put in with folded edges, the rubber prevents the fold from becoming flattened.

Methods of Driving.—Direct crank-handle drive is only practicable for small machines, the next stage consisting in the employment of a handled flywheel and spur gearing. On small, composite drives a direct motion can be transmitted by a handwheel, or, for thicker material, the

handwheel may be put on the pinion shaft and the spur gear turned thus. When power driving is adopted, the reversal is done by open and crossed belts, or by a friction clutch.

Cone Rollers.—Tapered gear-driven rolls are mounted in a machine for rolling conical shapes (Fig. 29), the rolls being adjustable for diameter and the thickness of sheet.

Mudguard or Wing Rolling Machine.—A quicker mode of forming the curves for wings than by beating is to employ a special machine provided with shaped rolls, and former or curving plates (Fig. 30). A complete wing can be rolled in about three minutes. Rollers measure 18 inches long in the largest models.

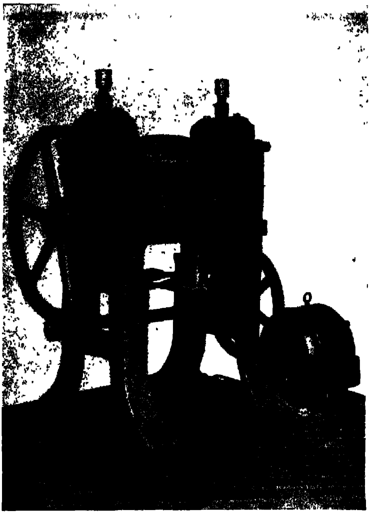


Fig 30.—Wing-rolling machine using shaped rolls and formers (Walter Frost and Co. Ltd)

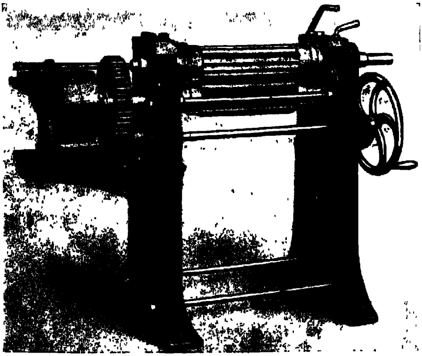


Fig. 31.—Corrugating rolls fitted with interchangeable sleeves. (Lee & Crabtree, Ltd., Shipley.)

Corrugating Rolls.—There are two sorts of machines possessing corrugated rollers. One type only converts flat or curved sheet intc corrugated by passing it between two hard steel rolls of suitable contour. Plain rolls may be fitted with hard steel corrugating sleeves, as an alternative. Examples are illustrated in Figs. 31 and 32.

Corrugated Curving Rolls.—To bend flat corrugated sheets into a

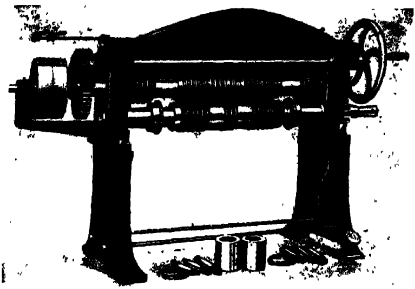


Fig. 32.—Corrugating rolls which have removable and adjustable sleeves. (Lee & Crabtree, Ltd.)

curve or circle for tanks, bins, roofing, etc., the other type of machine is required, carrying three rolls varying from 3½ inches to 7 inches diameter according to the size of machine. A steel bar is cast through the centre of the rolls, and both hand- (Fig. 33) and belt-driven designs are available.

Straightening Rolls.—These machines are required to a moderate degree by manufacturers of sheet-metal goods, and have four, five, or seven rolls. Sometimes the function is that of salvage, such as straightening out old drum bodies to serve for other purposes, either plain, or when passed through corrugating rolls. Narrow-roll machines are employed to straighten strips and angles.

Angle-iron Benders.—For bending angles, tees, and flat bars, which are used in making various sheet-metal structures, casement windows, etc., small machines are built on the general principle of two lower rolls and one upper, the latter being adjustable for height by means of a direct screw motion, or through a hand-wheel and worm gearing to the screw. The lower rolls are in halves, adjustable for taking any web thickness within the capacity of the machine. It is best, when bending complete circles with the web outwards, to do two rings simultaneously, because they then afford one another mutual support. A good many machines are hand-driven through a heavy flywheel and double gearing to the lower rolls (Fig. 34). Power drive by fast and loose pulleys is preferable when much of this work has to be done. As a guide, the capacity of a machine which is supplied either for hand, belt, or motor driving may be quoted:

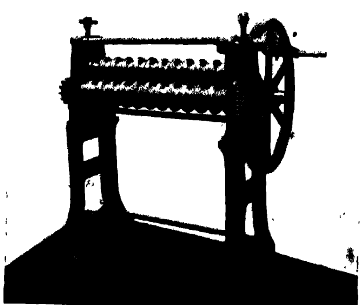


Fig 33.—Corrugated curving rolls. (Walter Frost and Co. Ltd.)

Angle or Tee Irons up to $\frac{7}{8} \times \frac{7}{8} \times \frac{1}{8}$ inch.
Flats up to $1\frac{1}{2} \times \frac{3}{8}$ inch.
Rounds and Squares up to $\frac{7}{8}$ inch.

Folders and Benders.—A comprehensive series of machines executes folding and bending operations by the use of mandrels, formers, dies, and blades. The light types are worked by hand or foot, and hold dies, which may be easily changed. An adjustable top beam is provided, and a gauge sets the position of the sheet. The results of folding operations are shown in Volume I, Chapter 9, with reference to small machines, but more elaborate formations are obtainable by employing dies such as the tinsmith does not require, almost anything being possible in this direction. A folder and bender is shown in Vol. I, Fig. 213. Special beams as well as dies are fitted for certain purposes, such as a rectangular-section beam for making box forms. Fig. 35 shows the sequence of processes in making tubes in a folding, bending, and box-forming machine, the strip being coerced around a roller by the action of the blades. Operations in making mouldings appear in Fig. 35. The final stage in folding a trunk may be observed in Fig. 36 as done on a power-operated folding and bending machine, gearing pushing up the tilting tables that perform the bending.

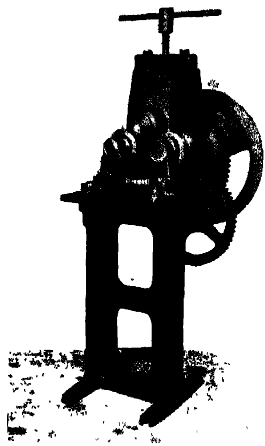


Fig 34.—Hand-driven angle-iron bender. (Walter Frost and Co. Ltd.)

Hand and Foot Machines.—Several kinds of folders and benders are worked by lever or pedal, the latter method being of course convenient in some cases, as it leaves the hands free for manipulation. Bench hand folders are constructed in capacities from 1 foot to 6 feet 6 inches wide, the latter dealing with sheets up to 19 s.w.g. Cramp folders grip the sheet, so that the hands are left free: this is accomplished by a lever-actuated eccentric. The bending apron is adjustable for different folds and thicknesses of material, and stops are fitted for repetition work. Blades for rounded folds and angle bends are supplied.

The larger cramp folders, mounted on standards, embody more mechanism. The front beam is balanced by a weight or weights, and is pulled up by one or two handles. The open-end frame type will deal

with sheets of any length. In one style of machine a parallel fence is attached, and adjusted by worm and wheel, with an indicator to show the width of sheet being bent. The fence is depressed by a treadle when sheets are required to pass through the machine. Short edges can be accurately bent, and when required these may be flattened and bent again for a double fold. In some classes of work this method avoids the cost of wiring. The heavy folding machines require wormgear and screw mechanism to actuate the top clamping beam. An example of this type takes $\frac{5}{16}$ inch thick × 8 feet 5 inches long.

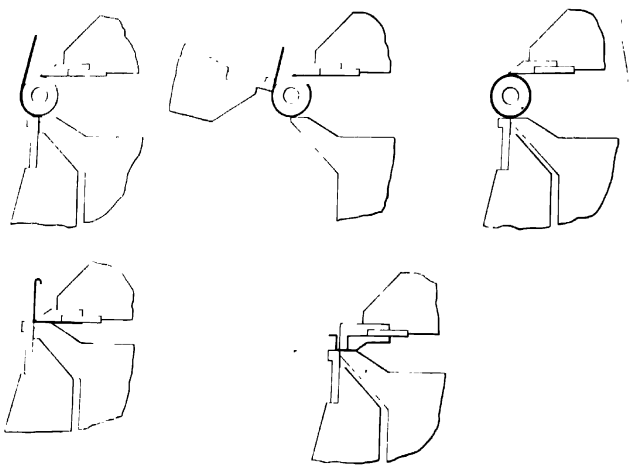


Fig. 35 – Some operations performed on a universal folder and bender (F. J. Edwards, Ltd.)

Trunk Bending and Forming Machine.—This is a specialised design, furnished in five sizes, for sheet $\frac{1}{8}$ inch thick by 31 inches long to 18 gauge by 81 inches. Unbreakable construction is guaranteed by using rolled-steel sections for the working parts. Auxiliary levers are provided at the back of the machine to use when extra heavy work is being done. The smallest shape which can be produced is $5\frac{1}{2}$ inches square. The end housing is attached by a pivot, so as to swing clear for removal of the finished trunk.

Universal Folding and Bending Machine.—The design of one universal machine includes the following details. The length, as sheet 6 feet by

14 gauge is handled, renders support of the bottom bed by a centre leg necessary, and the weight of the top clamping beam, which will lift 6 inches, entails motion by crank-wheels, bevel gears, and screws. The counterbalanced front folding or bending leaf is adjustable 2 inches for making round or sharp bends, and carries an additional blade for strength, this being adjustable when narrow reverse bends are required. An angle stop is attached for repetition work. Another universal machine is for 49 inch by 14 gauge sheet, and its three beams are adjustable so that tubes or channels up to $5\frac{1}{2}$ inches can be formed. The equipment includes a sharp and a round-edge blade, while a right-angle one is available for folding up the four sides of trays. The operations illustrated by Fig. 36 are executed on this style of machine.

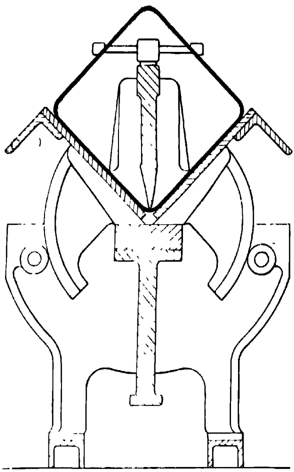


Fig 36 - Completion of trunk-folding operation

Hand and Power Drives.—The labour of pulling the handles of the foregoing types becomes tiring when the machines are used continually, and to save this exertion, and also to avoid the necessity for two operators on the larger machines, gearing is introduced. A crank handle actuates double gearing, the spurs on the beam being complete gears or segments. This drive is sometimes combined with the handle lift, which can be used when light sheets are dealt with. Stainless steel is more difficult to bend than ordinary steel, and thus gearing is advantageous for the thicker stock in this material. These hand-geared machines are made to bend up to 10 feet wide by $\frac{1}{4}$ inch thick.

Power Drive.—Quicker production on the large machines is derived from the equipment with belt drive, transmitting through double gears as described above. Added to a handwheel adjustment of the cramping beam, the operator is able to carry on with the minimum of fatigue. Cramping by power represents the limit of convenience, a friction-clutch connection from the driving shaft enabling this to be controlled.

Angle Benders.—A class of machine which occurs in various sizes and designs is the angle bender. This is a form of press having a vertically moving beam to which is fastened a die, opposed to one on the bed, and all kinds of sections may be evolved from the dies selected. It is

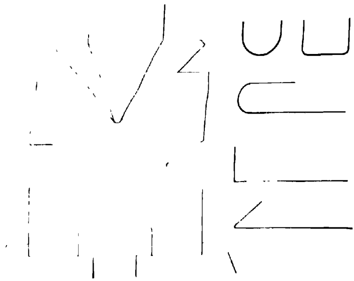


Fig. 37.—One bottom die will serve for various bends.

not necessary to use separate dies for every shape, because one bottom die, as represented by Fig. 37, will serve to form various bends, by transposing its position in relation to the knife-edge top die. For certain functions, the top die will be recessed in vee style, and the bottom one be of knife shape. Other dies are seen in Fig. 38.

Small Benders.—Lever or treadle motion draws down the beam in the lighter models, fixed on the bench, or on standards. These bend up to 18 s.w.g. by 4 feet wide in the largest size. An adjustable back guide locates the sheet.

Power-driven Benders.—Only light sheets can be bent on the hand or foot types, above which machines with belt-pulley or motor and gears must be used, driving an eccentric or crankshaft to reciprocate the beam. In

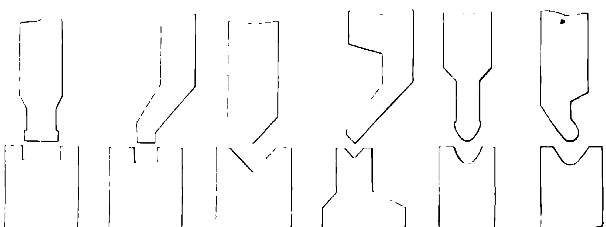


Fig. 38. Examples of dies used in bending-press

exceptional instances, the beam is stationary, and the heavy table moves up towards it. The beam, however, has adjustment by screws. The principal difference in construction of the power-driven machines is whether the mechanism is under or above, the latter being the system employed in the larger types, or "press brakes." As is the case with guillotine shears, the larger gears on benders generally have to lie below floor level on the underdrive types, sometimes an undesirable feature. The overdriven styles have nothing of this nature, and the base of the machine, when all the driving details are overhead, is left conveniently free for the movements of the operator.

Underdriven Benders.—The general mode of actuating the beam in these presses is through single or double spur-gear train on to the crank-shaft, which is coupled by rods to the beam. The adjustment for the position is made by means of locknuts on the rods connecting the crank pitment to the beam. Another way is to put one nut on each rod, lying between lugs on the beam, and adjust the nuts simultaneously by worms on a longitudinal shaft turned by a handwheel (Fig. 39). This saves time and ensures uniformity at each end. Pedal clutch control causes the beam to descend, and then rise to a stationary position at the top until required.

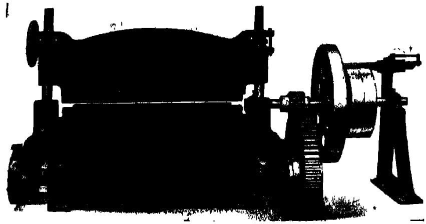


Fig. 39.—Underdriven angle bender (Lee & Crabtree, Ltd.)

The set of dies with which an underdriven machine is equipped for making ridgecaps, spouts, etc., is illustrated in Fig. 40, the main die being turned about on the machine as necessary to use the respective grooves. A pneumatic hold-down apparatus is incorporated in one style specially devised for corrugating sheet. Four cylinders and pistons are used to grip the sheet while the corrugation is being pressed; then pressure is released, for a feed forward. Sheets up to 12 feet wide are accommodated. The most powerful presses handle plate to ¾ inch thick by 6 feet wide, such being used for general angle bending. In addition to a wide choice of bending

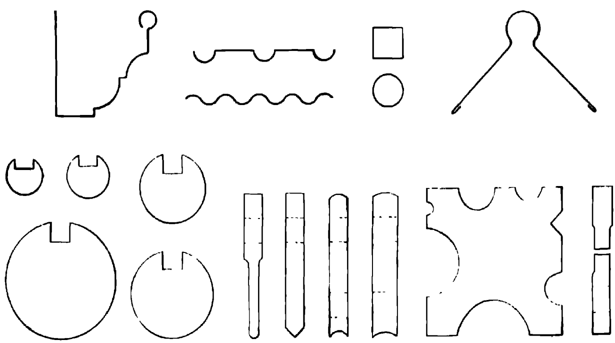


Fig. 40.—Standard sets of dies for gutter-bending machine and examples of work done

dies, such machines can be set up for gang punching, being fitted with fixed- or adjustable-pitch punches and dies.

Overhead-driven Benders.—There are more constructional and functional differences in these than is the case with the previously mentioned machines. The general scheme of the framing is either open-fronted, with a gap cast in the side frames to pass sheet to a certain distance, or the bending beam is centrally situated, and the frame has openings in line with its lower edge, in order that strips of any length may be passed through. Some designs are all cast iron, with solid side frames, or bed, standards, and top girder united by through bolts (Fig. 41). The ability of castings to resist side flexure is taken advantage of in a composite style (Fig. 42), the side frames being cast-iron box section reinforced by nickel-chrome bars heated to shrink to a tight hold The bed and beam are of rolled-steel plate. Another construction employs steel plate bolted together throughout, the only castings being those essential for the slideways, bearings, and so on (see Fig. 43).

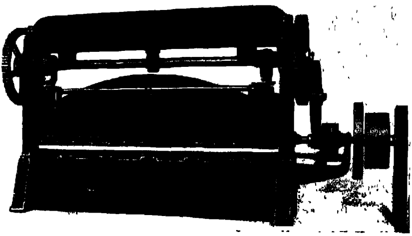


Fig. 41 - Overdriven angle bender. (Lee & Crabtree, Ltd.)

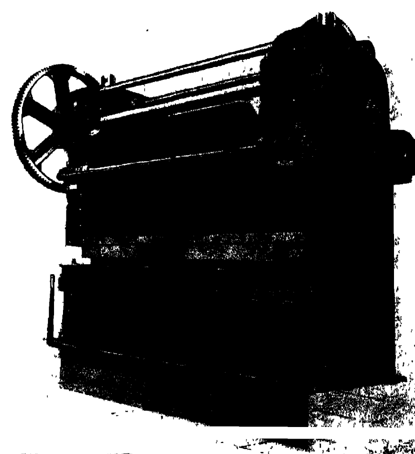


Fig 42 —12 feet 6 inch bending press, of composite construction.

The parts for driving by pulley or motor are disposed variously, but it is chiefly in the smaller sizes that any use is made of the ground for support, such as carrying the first-motion shaft bearings. Otherwise, in the taller machines, all the mechanism

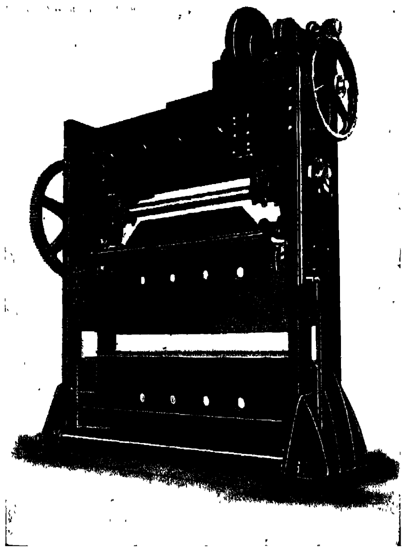


Fig. 43.—A 10-feet Rhodes' bending press of all-steel plate construction

rests on the back or top portions of the framing. The bearings for the crankshaft are attached to the underside of a cross beam in a good many presses. The resistance of the crankshaft to deflection is increased in one type by placing half bearings a little distance along the beam, close to the cranks. Some Rhodes' presses have bearings on each flank of the pin, and in other cases a forked connecting rod is used, straddling over the bearings. Even adjustment of the beam necessitates a duplex motion, comprising a horizontal shaft operating bevel gears that turn each screw of the connecting-rod couplings. Large presses usually have power setting to the beam by friction-clutch drive, or a chain connection which can be started up as required. A small electric motor is another means adopted in big machines.

Data relating to one large Rhodes' brake are :

Width of sheet bent	12 feet 6 inches.
Thickness	$\frac{3}{16}$ inch.
Tons pressure	150.
Standard stroke	3 inches.
Adjustment to ram	5 inches.
H.P. to drive	20 B.H.P.
Approximate weight	17 tons.

For special purposes the bed and beam of a press may be extended, so that extra long dies can be mounted to perform bending at a single stroke, instead of having to shift the strip or plate. A hornlike formation of the ram and table ends is another variation, this being furnished for the purpose of bending closed boxes. Occasionally shearing blades are substituted for dies. A hinged mandrel lying between supporting blocks

enables square box forms to be finished and closed in a set-up which utilises a press having a gap cast in the bed to allow the box to hang down. The first, second, and third bends are done between vee-section tools at the left hand of the bed, after which the concluding operation takes place on the mandrel, and this is unlatched and swung out to remove the work.

A large amount of bending is performed in power-presses which are applicable also for blanking, piercing, and other work. The advantages of the bending-press proper are generally the greater suitability for lengths and the lower cost of the machine. The length question is sometimes solved by casting apertures in the standards of the press, and these serve also to pass strip through when an automatic roller-feed is set up for blanking and other operations.

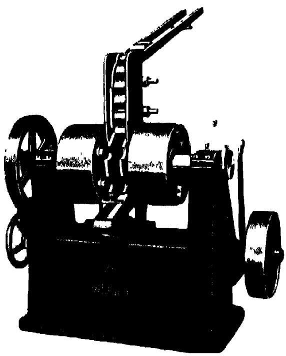


Fig. 44.—Automatic machine for flanging both edges of round cans

Flanging Machines.—A class of bending which occurs extensively is that of flanging tubes, cylinders, cans, boxes, covers, ends, and other articles either before any other work has been done upon them or subsequent to an operation such as forming. A large amount of such treatment is carried out in dies in the power-presses, but there are a number of machines made specially for different shapes, and actuated by hand or power. Some use dies, others rollers. A small bench machine of the former type flanges the ends of round cans for holding foodstuffs, etc., giving a perfect sizing and condition ready for seaming. Top and bottom dies on the ends of plungers are forced towards each other by links and a hand lever. The maximum capacity is $4\frac{1}{2}$ inches diameter and 5 inches deep. An automatic machine, acting on a similar principle with dies, is constructed to take the bodies on a sloping conveyor, down which they slide above a circle of chucks and are received in turn by the latter so as to come into line with the horizontal dies. Adjustments for different sizes may be made, for diameters from $1\frac{3}{4}$ inches, to $5\frac{3}{8}$ inches, and heights from 2 inches to 9 inches The speed is 200 cans per minute. Fig. 44 shows this machine.

A machine which flanges rectangular cans does this after they have been formed and locked, and they are held on a horizontal table while sliding dies perform the operation, one end at a time (Fig. 45).

Rollers are employed in small and large flangers, the body being held on flanging chucks. In the simpler machines the chucks are operated by

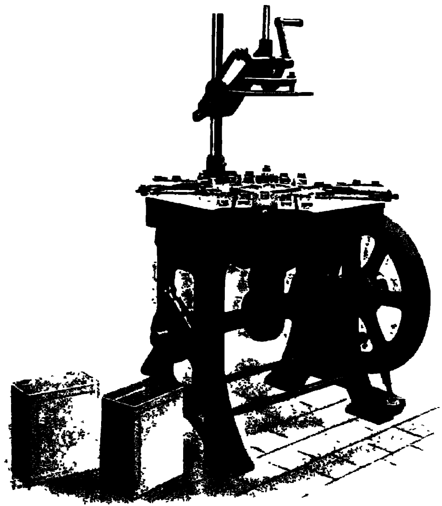


Fig. 45 —Die flanger for rectangular tins (Rhodes)

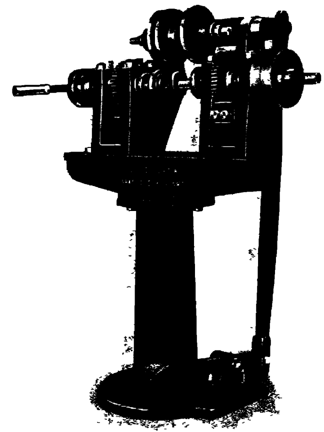


Fig 46 —Machine which flanges one or both ends

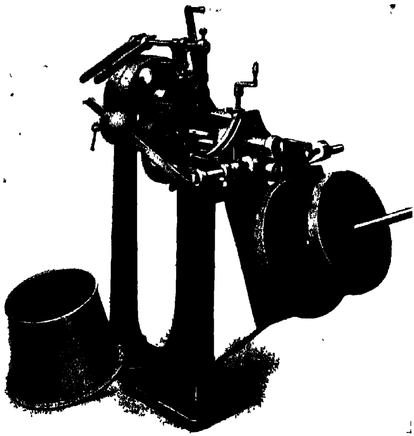


Fig. 47.—Universal swaging and flanging machine (Lee & Crabtree, Ltd.)

pedal, and the rollers by hand lever, but greater production is obtainable when a pedal controls both clamping and flanging (Fig. 46). Sometimes the flanging rollers are friction driven, but better work results when positive drive by gears is given.

When the output required does not warrant the expense of dies and a big power press for flanging shallow ends of large diameter, a roller-type flanger can be used. As an example, a machine is built to flange mild-steel blanks up to 36 inches diameter by $\frac{1}{8}$ inch thick, to a maximum depth of $1\frac{1}{2}$ inches. Fig. 47 shows a style specially useful for copper boilers.

For tube flanging the method is to support the tube upon chucks set apart from the machine frame a suitable distance, the outer chuck being adjusted by a bracket along screwed rods, the spindle of this chuck being pulled back by a hand lever for insertion of the tube. When in place, upper and lower power-driven rollers effect the flanging, being rotated by gearing from pulleys at the rear of the frame (Fig. 48). The smallest size dealt with is $2\frac{1}{2}$ inches diameter.

Flanging-and-Seaming Machines.—Flanging as a separate operation is avoided in some of the machinery designed for fast production. A

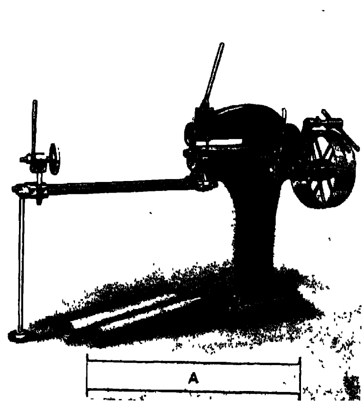


Fig. 48.—Machine which flanges tubes to the shape at A.

combined type of machine flanges and seams at one setting, and the system is applied particularly to heavy work, such as drums, whereby handling is lessened and expense for machines is reduced. Both vertical and horizontal types are employed; in the former the drum is placed on a chuck, and levers are pulled to operate the rollers, while a semi-automatic style (Fig. 49) requires only the treadle to be depressed, and the flanging and seaming take place automatically, one end at a time. A machine of this sort will handle drums up to 2 feet diameter by 3 feet high, heaviest gauge 18 s.w.g. A horizontal design of similar maximum capacity works automatically, doing 1,000 forty-gallon drums per day. The drum is rolled into the machine and located between the chucks by a balanced cradle, and the right-hand headstock, carrying a chuck and seaming rollers, operates by air pressure. The mechanism is on the top side of the chucks, and consequently the scale does not fall on it.

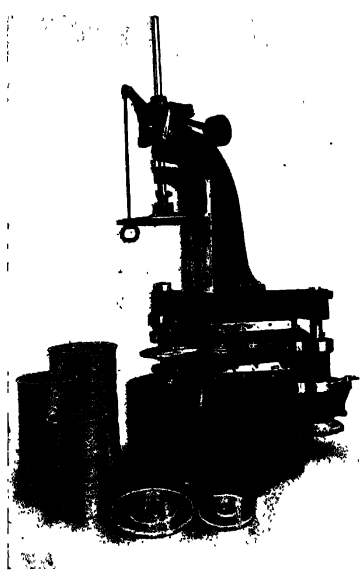


Fig. 49.—Semi-automatic flanging-and-seaming machine. (Rhodes.)

The most rapid output is obtained from a horizontal machine into which the drums are rolled (with the ends in position), and come out flanged and double-seamed (Fig. 50) at the other side. Two pairs of chucks, for double-seaming two drums simultaneously, enable about 4,800 five- or ten-gallon drums to be done in eight hours. If three pairs of chucks are fitted, the output is increased to 5,600 drums in the same time.

Beading Machines.—An important class of formative work consists of beading or swaging, the little machines of the tinsmith being elaborated into various power-driven types, some being capable of doing flanging as well, and others of forming multiple beads or corrugations. The general idea is that of driving upper and lower spindles by pulley and gears, and mounting beading rollers, of the contour required, on the ends of the

spindles (Fig. 51). Flat sheets are fed across a table fitted with a locating gauge, and tubes are supported on a mandrel. Sometimes reversing motion is provided to the rollers, worked by the lever that controls starting and stopping. The largest specimens of beading machines are those which automatically form the corrugations on steel drums (Fig. 52), either a continuous run of beads from end to end, or with a plain interval along the central portion. Rollers of the required profile make the continuous style, but the other can be produced one end at a time, or both simultaneously. Production varies from 750 to 1,500 per day, according to the size of drum.

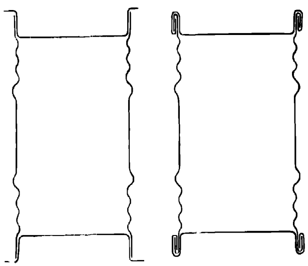


Fig 50 – Before and after flanging-and-seaming of steel drum

A different mode of action is noticeable in a forming machine in which the drum is placed over a cylindrical body, and two segmental beading rings expand, one after the other, to bulge the drum out at two spots equidistant from each other and from the ends.

Beading and bending are sometimes done in one operation in a machine of the type seen in Fig. 53. A hemming-and-beading machine with flat table and rolls at each side will execute a variety of operations, according to what shapes of rolls are mounted, *i.e.* rolls for flanging one edge, flanging both edges, flanging one edge and hemming the other, hemming both edges, hemming one edge and forming a bead, curling one edge and forming a bead, curling one edge, flanging the other, and forming a bead. One of these machines is constructed in standard models to deal respectively with maximum widths of 12½ inches, 15½ inches, and 18 inches, the minimum width in each case being 1½ inches. The maximum width of hem is $\frac{5}{16}$ inch, minimum $\frac{1}{16}$ inch.

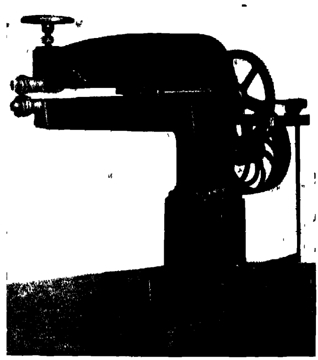
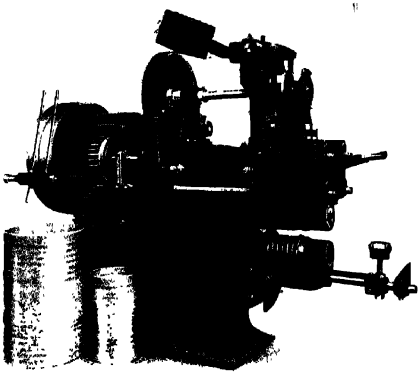


Fig 51 – Geared beading machine (Walter Frost and Co., Ltd.)

Multiple-roll machines are constructed to rapidly bead, flange, curl, or hem strips of any length, and if necessary bend to diameter, Fig. 54 being of this type. The strip in the multiple-roll machines is worked



52.—Automatic machine which corrugates 750 steel drums per day

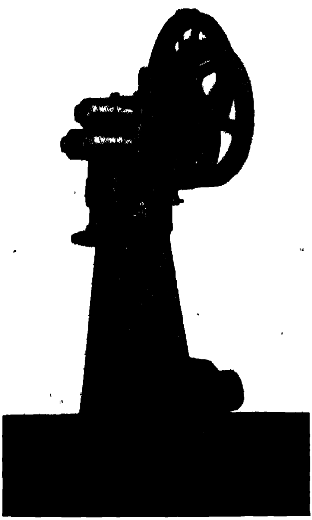


Fig 53 —Combined beading and bending machine. (Walter Frost and Co. Ltd)

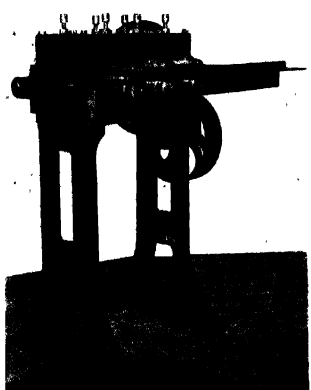


Fig 54 --Continuous forming machine for various operations on strip or coil material. (Walter Frost and Co., Ltd.)

gradually into the desired shape by a series of operations, the change effected per roll depending on the weight and quality of the material, and the necessity for avoiding wrinkles. Sometimes a shear is added, thus enabling coil stock to be utilised, instead of having to feed short strips. Certain shapes cannot be sheared, because of the distortion which would occur. In special cases an electrically controlled shear effects the severing so that strips may be cut to any desired length without cessation of rolling.

Wire-bending.—A large amount of wire-bending is necessary in connection with the manufacture of many sorts of sheet-metal articles, and this entails the employment of press dies, hand-manipulated appliances of a simple character, as well as many types of automatic machines designed for all manner of special purposes. The bending of a wire into square or oblong shape requires the use of a bench tool with a projecting square mandrel above which a vee-notched die is hinged, this being usually pressed down by a cam lever, so bending the wire to a right angle. Elliptical handles are formed by two rollers coercing the wire around a die of the required contour, a pair of levers giving the movement. For large-scale production, an automatic machine is available, taking the wire from a reel, straightening it, and cutting and forming the handles at the rate of eighty-five per minute.

Plate-rolling Machines.—In concluding this chapter, it may be of interest to point out that the principle employed in the majority of the machines described above is also used in the vast number of different sizes and types of rolling machine—or more briefly "rolls" as they are termed in the engineering industry—which are used in the manufacture of the metal sheets themselves. Here, it is usually necessary to heat the metal before rolling, and the ingots, in the form in which they are received from the foundry, are first of all raised to the desired temperature, after which they are passed backward and forward through the rolls until they are reduced to the required thickness, many successive processes of heating and rolling being required before the material has been worked down to the desired gauge of sheet. The various forms of sections, such as angles, tees, etc., are also produced by a similar process.

New Techniques.—An important development in recent years is the use of the "rubber press" for bending and forming certain classes of light-alloy and thin-gauge steel parts. A description of this technique is given in Vol. III, Chapters 1 and 8. Another development for shaping sheet metal is the comparatively new drop-stamping process described in Vol. III, Chapter 8.

CHAPTER 4

PUNCHING AND NOTCHING MACHINES

THE detrusive action which operates so well on sheet-metal, enabling it to be sheared into all sorts of shapes, is equally applicable for rapidly making holes and notches by the use of punches and blades. Drilling and reaming are employed in some classes of work, especially when sheet and strip products have to be united to thicker components, or when several thin parts lie together; but whenever possible, the punching method is chosen as being quicker and cheaper. The objections to it may be that the metal is stressed or cracked or deformed around the hole; but these faults are often due to the use of badly designed machines, inefficient or worn tools, or bad support to the sheet. Holes can be punched round, square, oblong, elliptical, oval, hexagonal, or of any contoured shape. A large proportion of the punching in repetition work is performed in the power presses, either as the only operation, or combined with others at the same time. Some fine kinds of mechanisms are subjected to finishing processes after punching, by reaming or grinding the holes, or using files for corrective and fitting purposes. The nose of a punch may be faced square across, or be concave to give a shearing action, or finished off at an angle for gradual penetration through the metal. A very slight clearance back from the cutting edge is necessary for freedom of working, and also to facilitate stripping.

Types of Punching Appliances.—Owing to the ease of penetrating thin sheet, a number of small hand-operated punching appliances are employed, actuated by the pressure of a lever. Some have quickly interchangeable punches. A small plier-like tool, no more than 7 inches long, will punch up to $\frac{3}{16}$ inch in thin stock. For greater power a cam and toggle mechanism is utilised in a heavier class of machine which will put a $\frac{17}{64}$-inch hole through 16 s.w.g. steel. A front pointer and side gauge combination enables holes to be punched accurately in any required position, and the punches and dies can be quickly changed. A more powerful style embodying a similar mechanism has a foot to attach to the bench, and the equipment comprises a set of fourteen punches and dies from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch. The throat is made deeper and wider, the gauge is set to a scale on the floor of the gap, and an adjustable stripper is fitted. With much longer leverage, on hand tools about 2 feet overall length, $\frac{3}{8}$-inch holes may be put through $\frac{1}{4}$-inch steel. The powerful screw action, which is employed in platers' and boilermakers' punching bears dealing with steel plate, is used to a moderate extent for sheet-metal

work, it being possible to punch holes of $\frac{3}{4}$-inch diameter through $\frac{5}{16}$-inch steel stock or angle by a bear weighing only $22\frac{1}{2}$ lb.

Small Punching Machines.—Various styles of small hand-operated machines are available to mount on the bench or on a standard. The pressure of a long lever is transmitted to the ram by a toggle, or an eccentric motion. Similar power, such as a $\frac{1}{4}$-inch hole through $\frac{1}{8}$-inch metal, is furnished in a series of machines which vary in the depth of gap, 5 inches, $6\frac{1}{2}$ inches, 12 inches, 15 inches, 18 inches.

Combined punching and shearing machines are popular with sheet-metal workers, as are the larger prototypes with platers and boilermakers The same frame and mechanism does duty for the two functions, and there is always the convenience of being able to do the respective operations with the least delay as regards manipulation. The less powerful combinations possess lever action, the punch ram occupying the usual position, while the shear blade can be arranged either in front of or behind the lever. The length of blade in this class of machine does not exceed about $4\frac{1}{4}$ inches and bars $\frac{1}{4} \times 2$ inches or $\frac{3}{8} \times 1\frac{1}{2}$ inches can be sheared. Greater ease of working is afforded by the geared bench types, having a vertical slide reciprocated by an eccentric on a shaft rotated by a large spur wheel turned by a pinion, and a heavy flywheel. The shear blades are at the top, and set at an angie for cutting hoop iron and rods of any length. The largest machine of this sort punches a $\frac{5}{8}$-inch hole through $\frac{3}{8}$-inch thickness. The alternative of driving by belt is offered in the same design, fast and loose pulleys being placed on the flywheel shaft.

A cast-steel frame affords the resistance against breakage which is always a risk with cast iron, but many hand-lever punches are constructed in light and unbreakable manner from steel plate, with angles riveted on to form the feet, and the mechanism fastened by bolts. One machine, that punches a $\frac{1}{2}$-inch hole through $\frac{3}{16}$-inch thickness and has a 6-inch gap, weighs 120 lb. An eccentric pin is moved by the hand lever, and through the medium of links on each side the motion is transmitted to a block on top of the ram, which slides through a bearing that also has the two stripper plates bolted to its flanks. The mode of changing the dies is by loosening the bolt of a split block attached to the frame. A slanting die for supporting flanges is supplied. In smaller machines a slidable die is fitted, to be locked by means of set screws when either one of the desired holes has been aligned with the punch. In two sizes of these machines the series of holes run respectively $\frac{1}{4}$ inch, $\frac{3}{16}$ inch, $\frac{1}{8}$ inch, and $\frac{5}{16}$ inch, ' inch, $\frac{3}{16}$ inch.

The capacity of the largest machine of the series, when dealing with sections, is :

In webs of Joists :

From $3 \times 1\frac{1}{2}$ inches $\times$ 4 lb. up to 9×4 inches $\times$ 21 lb.

In webs of Channels :

From $3 \times 1\frac{1}{2}$ inches $\times$ 4·6 lb. up to $8 \times 2\frac{1}{2}$ inches $\times$ 15·1 lb.

In flanges of Joists:
From 3 × 1½ inches × 4 lb. up to 6 × 3 inches × 12 lb.
In flanges of Channels:
From 3 × 1½ inches × 4·6 lb. up to 6 × 2½ inches × 12 lb.

Increased power to enable heavier work to be done is furnished in a range of machines of the plate construction type, by the use of a large ratchet wheel in conjunction with the hand lever. The latter may be applied to actuate the eccentric motion direct, or the ratchet gear can be brought into action to enhance the leverage, or a treble gear be employed to transmit through a pinion and quadrant to the ratchet wheel.

Punching Presses.—The foregoing types of machines are all for making relatively small holes, but there is a large amount of sheet-metal work which must have round, square, and other-shaped holes much beyond the scope of such machines, and punching presses are employed for piercing of this character. Eccentric motion usually moves the ram, which is of massive build and slides in broad guideways, and the bed has a large area to receive ordinary or specially formed dies; or a horn extends from the frame when it is required to carry shaped stampings or other parts. Treadle control is generally installed, though in some cases the stop motion is operated by a small handle at the side of the slide. Methods of driving include direct by belt flywheel pulley on the eccentric shaft for the lighter duties; single-geared from a flywheel and pulley shaft; double-geared ditto, and single-geared motor drive, the pinion meshing with a ring of teeth on the flywheel.

Capacities.—A maximum stroke of from 1 inch to about 2½ inches is provided in the smallest and largest machines respectively. The maximum distance from the ram to the bed ranges from 6 inches to about 20 inches in different sizes and models, but some machines have an adjustable table elevated on the column by means of a screw, affording a difference of from 10 to 20 inches in various types of presses.

Fig 55—Punching machine for large sheets. (Rhodes.

A good depth of gap is essential for punching some kinds of sheet products, and many of the bigger presses have a deep gap as befitting the

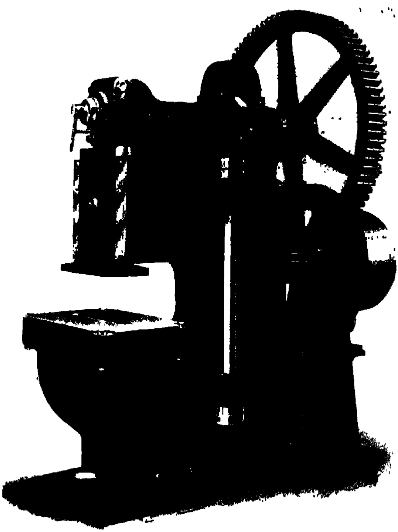


Fig. 56.—Powerful punching press, having frame reinforced by nickel-chrome steel tie-rods (Rhodes.)

size of the frame; but quite low-power types may possess a deep gap for special purposes (Fig. 55).

Reinforced Frames.—The great stress involved in punching large apertures has led to the introduction of reinforcing bars which tie the gap against springing and possible breakage, the life of the punches and dies being also prolonged. These bolts, of nickel-chrome steel, are placed in open slots at each flank of the frame, and provided with locknuts at top and bottom to put on the tension (Fig. 56).

Beds and Tables.—The bed of a press is usually square or oblong for ordinary purposes, and slots or holes enable the die to be attached. Sometimes a very large table is furnished for convenience of manipulating thin sheet to various positions, and on the contrary a very small area will suit for a press doing repetition operations on pieces of little width or diameter. A fairly long horn or bracket (Fig. 57) stands out from the frame in some designs, so that rectangular or cylindrical bodies may receive support for punching holes on the sides or edges. In a bung-hole punching machine, the steel drum rests on a convex-faced die fastened to the horn, and the ram carries a punch which makes the hole, and stamps a shallow recess around it (Fig. 58). The heads of the drums are dealt

Fig. 57.—Light punching machine with horn to support hollow stampings. (Rhodes.)

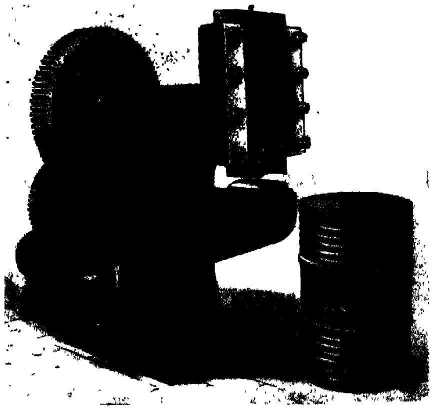


Fig. 58 — Rhodes' punching machine for bung-holes of drums.

with in a different style of machine with a cross-beam holding two punches, which can be adjusted to any desired distance apart, to make the holes simultaneously near the edges of the head.

Automatic Feeds.—A long sliding table, on a bed resting on supplementary standards some distance on either side of the main frame, is fed intermittently by ratchet mechanism to propel strip or sheet for successive holes. The amount of feed is adjustable through a slotted crank disk. Another sort of feed, also variable in pitch by a crank disk, actuates a double-roll apparatus. Automatic raising of the rolls at each stroke of the slide can be furnished, so that work which requires a pilot in the die is allowed to centre or adjust itself. The crank-driven presses which are utilised for general stamping purposes may be equipped with a turntable arrangement for punching operations on large numbers of pieces. Friction or pawl mechanism rotates the turntable, which is accurately indexed and locked during the punching.

Gang-punching Machines.—The counterpart of the multi-spindle drilling machines which are installed in machine shops for repetition work occurs in the form of gang-punching presses. These put rows of holes in strips and sheets for tanks, cylinders, doors, frames, panels, transformer plates, and many other components. Generally a beam, driven like that of a guillotine shear, is employed to operate the tools, the main difference consisting in the method adopted for holding them at fixed or variable pitches, and of attaching special die supports for specific objects. One of the light machines resembles an under-driven guillotine shear, and takes sheets 36 inches wide and up to about 18 s.w.g. Sheets of any length can be punched near the edges because of the gaps cast in the standards. A more powerful type having an overhead drive will punch fifteen ½-inch holes in 14 s.w.g. mild steel, and another, taking a 12-h.p. motor, puts through thirty-eight ¼-inch holes in ⅛-inch sheet 50 inches wide. In an example where adjustability for different pitches is necessary,

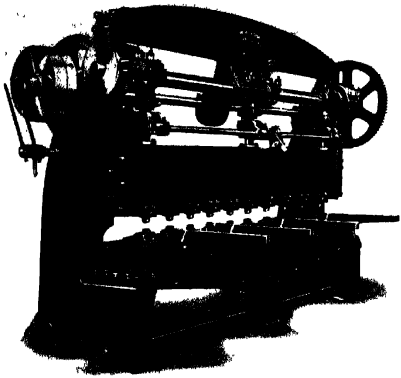


Fig. 59.—Rhodes' multiple punching machine

this requirement is met by fixing the punches in tool-boxes bolted to the beam (Fig. 59).

Special tables are mounted for such purposes as supporting flanged objects, motor-car doors, for instance. To make the round and oblong holes in sections for window-frames, adjustable die-blocks are fastened to the bed, and a cam-operated automatic stripper firmly holds the bars on the die before the descent of the punches, and releases on their ascent. The latest types of gang-punching presses are built up in unbreakable fashion, from rolled-steel plates bolted together.

Rotating-spindle Punch.—A small machine is constructed for punching and countersinking nail holes in motor-car bodies and other parts. The spindle is belt-driven at high speed, the sheet rests upon a small die, and the spindle is forced down by a treadle and lever motion.

Nibbling Machines.—The nibbling principle is a special application of punching; it competes with some kinds of shearing, but will effect certain operations that cannot be accomplished on a shearing machine, and also cut out apertures which could only be otherwise made by a specially shaped punch and die outfit in a powerful press. A small circular punch, reciprocating at a rate of from 350 to 1,400 strokes

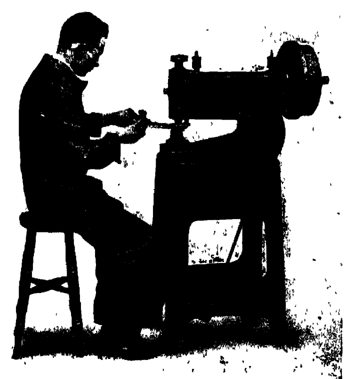
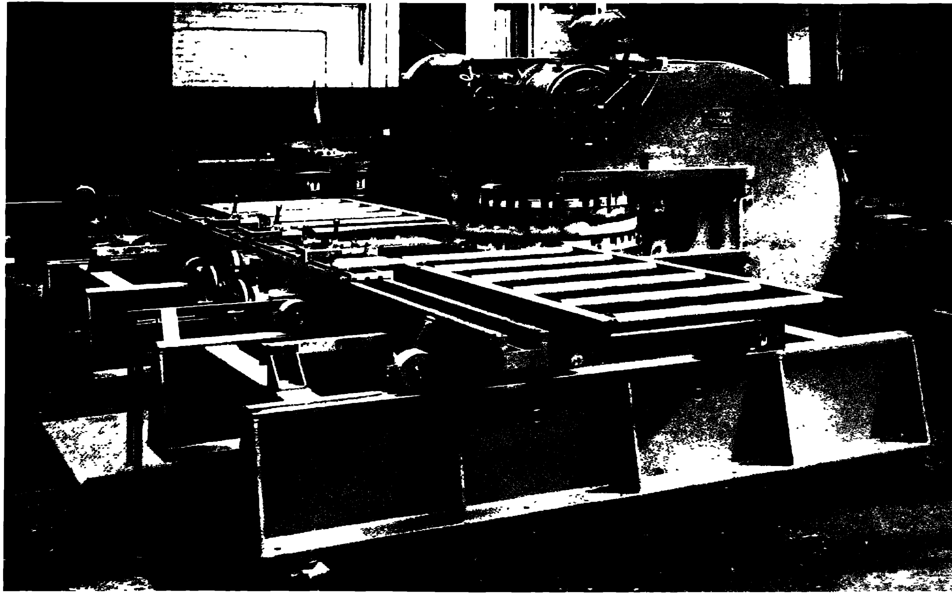


Fig. 60.—High-speed nibbling machine which cuts outlines by a punch. (J. B. Stone & Co., Ltd., London.)



(Scottish Machine Tool Corp., Ltd.)

A LARGE MULTI-PUNCH MACHINE

A large multi-punch machine equipped with 32 punches. The head can be rotated to bring any of the punches into position, and each punch is capable of individual adjustment

per minute over a die, nibbles out the design (Fig. 60), and only a slight finishing is necessary to make a smooth edge. Standard punches of $\frac{3}{16}$-inch, $\frac{1}{4}$-inch, and $\frac{3}{8}$-inch diameter are used on different sizes of machines, and steel to $\frac{1}{4}$-inch thickness can be cut by this method. A maximum speed of 30 inches per minute can be obtained, but some machines will operate a short shearing tool as an alternative for cuts where the conditions are suitable, and a speed of 6 feet per minute may be thus attained. Large apertures, rings, and disks are cut in this way. The Pels machine in Fig. 61 is seen to have such a blade, which can be brought into action when the punch is removed. The sheet to be cut rests on the supporting tables fitted on either side of the die, which swivel, and may be adjusted for height. The cutter head is rotatable to a full circle, so as to present the blade for cuts in any direction, and the stroke is adjustable for different thicknesses of material, a scale being provided for this setting. Some sorts of cutting, such as that inside thick sheet, must be made by the nibbling punch. An adjustable stripper lies over the work. Templets are used for some contours, being clamped to the sheet, and circles are done by the aid of a centring attachment. A modified type of machine is built with the punches in the form of narrow, tapered, flat-sided tools, for cutting out any shapes in the middle of sheet or hollow parts, also for trimming hoods, radiators, mudguards, and such-like. The upper blade has a speed of about 1,400 strokes per minute. A shorter, stouter blade is employed for thicker metal, up to, say, 14 s.w.g. The frame of this machine is electrically welded, affording a rigid and non-yielding body, which is guaranteed against breakage. The motor drive shown in Fig. 61 provides a high speed for light work, and a slower one for heavy sheets, the stepped pulley enabling the changes to be effected. Special tools may be fitted

Fig. 61.—Nibbling machine using either a punch or a short shearing-blade. (Henry Pels & Co., Ltd., London.)

to perform flanging or straight or curved beading, and also for joggling, that is, setting down a portion of a sheet to another level. The lightest machine in the series, nibbling or shearing sheets up to $\frac{1}{8}$ inch thick, requires a $1\frac{1}{2}$-h.p. motor, and the heaviest, with much deeper gap and dealing with $\frac{3}{16}$-inch steel, takes $6\frac{1}{2}$ h.p.

Slotting Methods.—Although the slotting machine is more a tool for dealing with castings, forgings, bars, and plates, it is sometimes of service in sheet-metal work, if packs of plates or strips are clamped down and machined to straight, curved, or profiled outlines. Very accurate results are attainable in this manner. The precision slotters or vertical shapers suit well for this class of cutting, also the light tool-room slotters. Inside or outside cutting is done, and the circular table enables curves to be produced. For small batches of similar shapes, or experimental purposes, the method is better than hand work, exact uniformity of each unit being assured. The finishing process around the edges, necessary when they are nibbled, is eliminated, while the cost of dies is avoided, such as would be used in press production on a larger scale. Milling on a vertical machine is an even better way if the finish of the angles permits the use of a mill, and control by means of a templet or profiling attachment is often practicable. Many kinds of sheet articles have holes whereby the pack can be located on pegs on the table or on a jig, or in a machine-vice. In other cases plain units are all set by a square up from the table, or backed against a block bolted to it. If the outline is not worked from scribed lines or by a profiling attachment, a specimen piece or templet may be placed on top of the pile for this purpose.

Sawing Outlines.—Another alternative to the nibbling method is that of sawing. This is not adopted much for manufacturing purposes, but chiefly for single pieces or small numbers, as well as for preparing patterns and templets. It gives a clean cut without risk of distortion. The jigsaw is the machine usually employed, and one or two quick-acting clamps hold the sheet on the table just firmly enough to prevent it from lifting. For finishing and cleaning-up operations a file can be substituted for the saw. On some machines the saw is in the form of a coil about 50 feet long, stored in a magazine and drawn from as requisite. As the machines are also utilised for cutting out dies used in sheet-metal work, the capacity is generally for a thickness of at least 2 inches, an oilstone being employed, after filing, to impart a fine finish. (See also Chapter 15, Vol. II.)

NOTCHING MACHINES

Special machines are built for cutting out vee or other recesses in the edges of sheets and strips for folding and jointing, and also notches and slots in armature disks and segments, tooth spaces of circular saws and ratchets, sprockets, and other objects. The principle is either that of using a tool or punch shaped with the required number of teeth, the sheet being supported upon a die; or pitching is done so that one tool edge

successively punches the notches as the machine indexes from one position to another. As regards circular work, the whole set of slots or notches in a comparatively small disc may be pierced at one stroke by dies in a power press if the number demanded warrants the cost of the dies, otherwise an indexing type of machine is used for the process.

Belt-driven presses serve for vee and other notching, a guillotine style of machine carrying the sheet, the bottom die lying level with the table so that the sheet can be pushed forward against the guides which control the position. The machine has open ends, so that any length can be dealt with and the clutch for starting the descent of the beam is operated by a pedal. The body blanks for tins, notched out square or at 15°, are done in a foot-press, the die of which is pulled down on depressing the pedal, while adjustable gauges on the table locate the work. The notches on hinges are also cut on this machine.

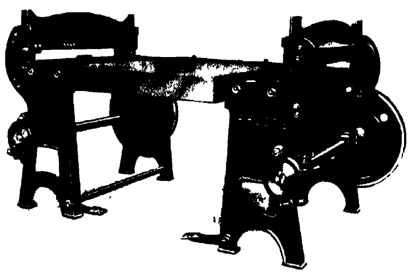


Fig. 62.—Duplex notching machine for sheets to make drums

A duplex machine (Fig. 62) designed for notching the corners of both edges of the body sheet for steel drums has a guillotine style of frame and beam at each end of a long table, the position of the dies sideways being adjustable. Sheets up to 3 × 7 feet may be notched.

Armature-plate Notching.—This important section of punching practice is responsible for a good many differing designs of presses with special mountings for the disks or segments. The results obtained are equal to those from press dies, which are expensive, especially in the larger sizes. As many as 700 notches can be cut in a minute on the small high-speed machines. The range of diameters dealt with by various presses extends from 1¾ inches to about 18 feet.

Forms of Notching.—The notches in rotor and stator plates are of various shapes, comprising oblong reaching from external or internal diameters, oblong with undercuts, and oblong with closed ends. In making small armature disks from square sheet, they can be notched and blanked at one operation, with a T-shaped punch (Fig. 63). The sides of the punch are made at an angle as seen, so that the scrap is completely cut away. The procedure in making small rotor and stator plates on an external notching press is first to punch the centre hole, with its keyway, and notch the circle of slots for the stator, after which the centre portion

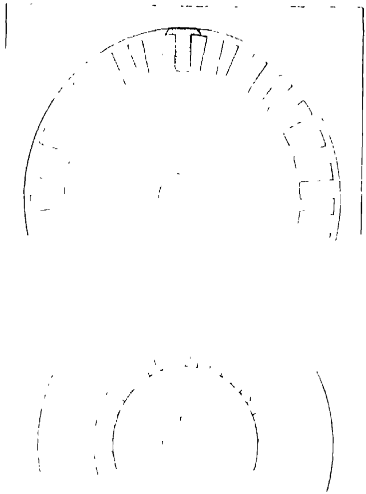


Fig. 63.—Upper figure shows notching and blanking at one operation. Lower figure, making stator and rotor plates.

is blanked out. This now has its notches punched, and finally a grinding operation is carried out on the inside circumference of the stator disk and the outside circumference of the rotor disk. The accurate pitching of the notches in armature segments, which are used for large diameters, is ensured by feeding the table around continuously without stopping or reversing. As each complete circle of segments is notched in the same way as if the plates were all in one, there is no inaccuracy in the notches which are cut at the joint lines between the several segments.

Principle of Operation of Notching Presses.—A standard or a modified design of open-front short-stroke press is furnished with a special table for notching small disks, but many of the larger machines have the standard cast integrally with a projecting bed machined to carry the slide and dividing apparatus; or a plate of large area has slots whereby the apparatus is fixed. Intermittent turning of the vertical work-holding spindle is performed through the medium of a crank disk on the end of the crankshaft, moving rocking levers and thence a friction-band that effects the partial rotation. Alternatively, a toothed wheel and pawl can be employed, the pawl stroke being regulated to give the required pitching. In the friction-band system a division wheel suitable to the number of notches in the armature disk is employed, and the drive feeds the division wheel round against a stop, which ensures a definite location. In the sliding-saddle style of construction, all the mechanism is on the saddle, and its resetting for different diameters does not interfere with these details; but the large models with plate type of table require longer to set the positions of the indexing and locking units.

Press for Small Disks.—The principal features of one press which notches disks from $1\frac{3}{4}$ inches to $4\frac{1}{2}$ inches diameter are as follows: the standard is cast with a T-slotted bed to which are bolted gib plates and a gib strip retaining the vee edges of the work-holding element; a $2\frac{1}{2}$-inch diameter dividing wheel is used, and a stripper plate with springs

lies at the bottom of the ram; the speed of the flywheel is varied, according to the diameter of the disks, from about 300 to 600 r.p.m. and a hand lever enables the notching to be stopped instantly at any point. When the disk has completed a revolution, the press stops automatically.

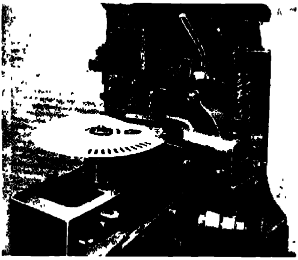


Fig. 64.—Attachment for punching half notches at the edge of a disk

High-speed Press. A machine of moderate capacity, taking armature disks from $3\frac{1}{2}$ inches to 17 inches diameter has its bed cast with the column, and the sliding table is regulated to and fro by a screw and hand-wheel. The bed on which the dies are fastened is adjustable from front to back, and when small dies are mounted the bed is placed so that its front edge comes flush with the outside of the die, and thus the spindle may be set close up to the die, in order to notch the smallest diameters of disks. A standard size of dividing ring of $8\frac{1}{2}$ inches is chosen, this being easily changed for another, according to the number of notches required. The height of the pallet plate, to suit the dies, is adjusted by means of a fine screw. From 350 to 600 notches can be cut in a minute, depending on the size of plate and the number of notches. With a special attachment located at the side of the column (Fig. 64), half-round notches can be made on the periphery of a plate which has been perforated with notches some way in from the outside. Belt driving through a cushioned flywheel reduces the shock of starting the press. A similar machine, but driven by a 3-h.p. motor through a tex-rope, includes a frictional cushioned driving wheel and automatic brake (Fig. 65). The usual number of strokes is 600 per minute.

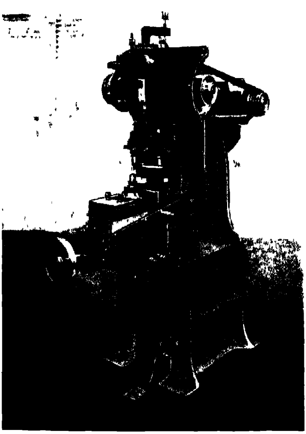


Fig. 65.—Motor-driven high-speed notching press

Ratchet-feed Press.—The friction-band method of feeding is preferable for high-speed operation (Fig. 66), but on a slow-speed notcher, of capacity from 6 inches to 44 inches and similar general design, the

Fig 66.—High-speed notching press having friction-band feed

ratchet-wheel system may be found. Connection from the crankshaft to the ratchet pawl takes place by way of spiral and bevel gearing to a crank disk on a vertical shaft at the saddle, which possesses adjustment along the bed for the various diameters. To adjust the machine for the number of notches required, the locking bolt has first to be withdrawn from the ratchet wheel. Then, by means of the crank disk, the stroke to suit the desired movement is altered, and the correct relationship of the strike to the indexing is made by a right- and left-hand thread on the rod which connects the crank pin to the pawl.

High-speed Press for Disks and Sprockets.—A powerful type of machine for general service on armature disks, circular saws, sprocket wheels, and freewheels has spur and worm-wheel transmission from the crankshaft, giving variable stroke to the friction-band which performs the pitching. Changeable dividing wheels of 12 inches diameter are used, the maximum capacity being for 24-inch disks. Speeds of notching differ according to the class of work and the number of notches. An average rate of 360 notches per minute is attainable on armature plates, 150 per minute for small sprocket wheels, and 200 for large. The fewer the number of notches, the less the speed must be: as low as 100 strokes will be necessary when cutting a minimum of six notches, the angular motion of the dividing wheel being so large.

A special automatic feed gear is applied when cutting chain-wheel sprockets or freewheels, the action being to reset the work-carrying

Fig. 67.—High-speed press embodying special gear for roughing and finishing cuts on sprockets. (Taylor & Challen, Ltd.)

spindle into three positions successively after each revolution. A cam and roller mechanism gives the motion, which is arranged to provide roughing, second, and finishing cuts. The amount of feed forward for the second and finishing cuts is $\frac{1}{100}$ inch. Fig. 67 shows the press.

Press for Internal Notching.—A large-area table is required to carry the attachments for internal notching of armature plates and segments, and the connecting-rod which actuates the friction band for feeding must be arranged with a lateral adjustment to suit the different diameters. This is accomplished by causing the crank disk on the crankshaft to rock

Fig. 68.—Press for internal notching of armature plates and segments

a lever having a long hub, and lugs below at each end, with a pin in between, along which the boss of the connecting-rod may take any lateral position. The equipment bolted to the table consists of a ring on which the division plate rotates, carrying the pallet plate with it, the armature plate being held on it by spring clips. At each pitching the friction-band forces the division wheel back to a solid stop attached to the table, the stop being adjustable, so that the notches may be located correctly in relation to the register keyway in the blank. Various sizes of these machines deal with plates having minimum pitch circles from 4 inches up to 46 inches. The maximum number of strokes per minute

reaches 360 in fine-pitch work of moderate size. A 40-inch machine is seen in Fig. 68.

Notching Large Plates and Segments.—Some special features of design are noticeable in the case of the largest presses, which will take work of 12 feet or more diameter, a long bed and spider-type supports being required. There are two methods of supporting segments—by what may be termed the individual system, and by the continuous system. In the first, two graduated radial arms support the segment and hold it by adjustable grips A quadrant or master rack with appropriate number

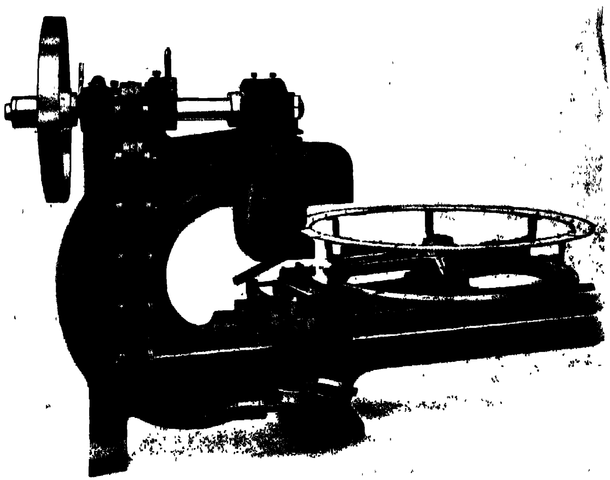


Fig 69.—Twelve-foot press for continuous notching of armature plates and segments

of teeth goes on the saddle, and there is a screw-setting device for varying the position of the initial notch.

In the continuous method, which is preferable, a complete circular gallery or table is used (Fig. 69). The normal capacity of a press built on this principle to 12 feet maximum can be increased to 18 feet by bolting an extension bed to the flanged end of the bed, and fitting a larger dividing wheel. For internal notching, the bracket bolted to the nose of the press to carry the cutting die has to be reversed so that its U-shaped gap faces towards the press frame. The number of notches punched on these big machines varies from 30 to 100 per min., according to the size of the plates or segments.

CHAPTER 5

RIVETING

RIVETING is one of the most widely used methods of fastening two or more parts together to form an assembly, although for certain applications it is gradually being replaced by welding. The uses of this process are very wide because the joints are strong, and can be made airtight and watertight. As mentioned above, welding has replaced riveting in many instances, this being due chiefly to the fact that it is quicker. Welding could be used more extensively in aircraft construction and in all probability will be used so in the future when the process becomes more advanced, but there are certain limitations at present, these being mostly connected with the alloy materials being used, which are difficult to weld without causing deterioration of the structure due to corrosive action.

Fig. 70 Riveting small components with equipment built up specially to suit the operation. Basically, it comprises a standard Broomwade hydro-pneumatic intensifier, an operating cylinder, and a special yoke.

Riveting possesses the advantage over other processes that, when done properly, the joints are "tight," totally excluding the atmosphere from the mating surfaces, which is the primary cause of corrosion. When this is the chief factor involved, the strength of the rivets is not of vital importance because the overlapping of the plates almost doubles the elastic limit, and also because so many rivets are used to make the joint

"tight" that the joint usually is the strongest part of the structure. On the other hand, for most applications strength of rivets and bolts is of great importance, and it is thus necessary to be conversant with the technicalities and mathematical calculations of this subject.

Types of Joint.— When dealing with problems involving shear loading it is essential to take into consideration whether the members or parts concerned are in "single shear," "double shear," or "multiple shear." The illustrations in Fig. 71 will help to make clear the meaning of these terms. In Fig. 71 (*a*) is shown a rivet fastening together two plates which are subjected to stress in the direction indicated by the arrow; in this case the rivet is denoted as being in "single shear" because the total load must be resisted by a single traverse section. With regard to the rivet shown in Fig. 71 (*b*), two sections are concerned in resisting the load and the rivet is consequently in the position of a "double shear," from which the term used is derived. Assuming that the rivets in both of these cases are of the same size and the loads are of equal size, the shear stress in the first example will be exactly double that of the second example.

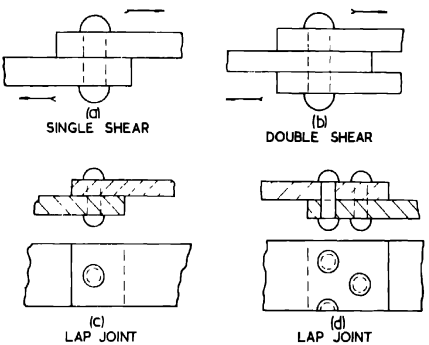


Fig. 71.—Examples of (*a*), single shear, (*b*), double shear, (*c*), single-rivet lap joint; and (*d*), double-rivet lap joint.

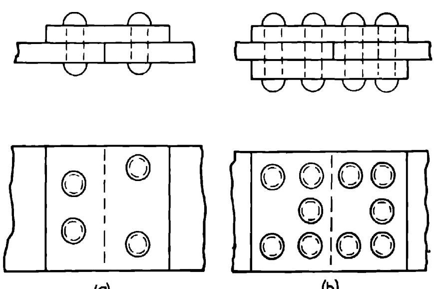


Fig. 72.—(*a*), Single-riveted butt joint, and (*b*), double-riveted butt joint.

The two main classes of riveted joints are "lap joints" and "butt joints." Each of these is divided into other groups consisting of single-riveted, double-riveted, and so on examples of which are shown in Fig. 71 (*c*) and Fig. 71 (*d*), and in Fig. 72.

To determine the efficiency of a riveted joint it is necessary to calculate the resistance at each row of rivets, the strength of the rows often being equal. As an example, at one row the plate alone may have to accept the load while at an adjacent row reinforcement is provided by the shear resistance of another row of rivets. The strength of each row must, of course, be considered for all possible types of failure.

The ratio of the lowest value thus determined to the strength of the undrilled plate provides the efficiency of the joint, *i.e.* :

$$\text{Efficiency } \% = 100 \frac{\text{minimum strength of joint}}{\text{strength of undrilled plate}}.$$

Aluminium and its Alloys.—For the riveting of aluminium or aluminium alloy sheet it is good practice to use rivets of the same metal. In some cases, however, such as the joining of heavy-gauge duralumin plate and sections for structional work, steel rivets are often employed, suitable precaution being taken to avoid corrosion. Aluminium and other non-heat-treated alloys can be riveted cold, even in the case of heavy-gauge sheet, cold riveting being also possible with duralumin and similar high-strength alloys if certain conditions are observed.

Only in the case of small sizes can duralumin rivets be driven in the fully heat-treated state. As the size increases the tendency for the heads to crack during the process becomes more pronounced, and in such cases it is necessary for the rivets to be given heat treatment to 480° C. and quenched, after which they are soft enough to be driven cold ; after a short time in position they " age harden " and regain their original strength. As this form of hardening commences immediately after quenching, the rivets must be used up in batches within approximately two hours. It is possible to retard the age-hardening process by keeping the rivets at a low temperature, such as storing them 0° C. in a refrigerator, where they will remain soft for at least a day. This is quite common practice in large aircraft factories.

Duralumin rivets may be driven hot provided that the temperature is kept under careful control, the cold metal of the plates acting as a quenching media and causing the rivets to harden in position. Heating is usually done in a lead bath held at the requisite temperature, although gas or electric heating is also frequently employed. Salt-bath heating is not desirable because the salt is inclined to adhere to the rivets and cannot be washed away on completion of the joint. Because of the difficulties in temperature control, hot riveting with aluminium-alloy rivets is not generally employed for structures assembled on the site, but steel rivets are used instead, these being driven hot in the usual manner. The possibility of the hot steel rivets overheating the duralumin and having a detrimental effect on the alloy does not occur, provided the plates being joined are not less than ¼ inch in thickness. In spite of this, however, some engineers insist on cooling the rivets with blast or spray immediately they have been formed.

Spreading of Metal.—When working on a line of rivets the metal has a tendency to "spread" if the rivets are closed one after another in sequence, with the result that towards the end of the row the holes do not match up. For this reason, experienced operators first drive a few rivets at random along the length, then filling in the spaces between. In the case of thicker plates the usual procedure is to bolt them together before riveting.

The overlap on a single-riveted joint of aluminium plates should not be less than four times the rivet diameter, with a maximum of five times. For high-strength alloys this figure can be reduced to two or three respectively. The use of too small an overlap will result in a wavy edge. In order to allow for a certain amount of "spread" in the rivet shank, the rivets should be an easy fit in the holes before hammering over. When using countersunk rivets it is essential that the form of the head exactly corresponds with the angle of the hole in the plate, otherwise considerable distortion will occur.

For thin sheet-metal work the "depressed" type of riveting gives good results, *i.e.* the edges of the metal surrounding the holes are formed with a punch, causing a countersunk depression which "mates up" with the adjacent plate and thus locking the two together; this is known as "dimpling." With the use of countersunk rivets this method produces a flush surface and a good sound joint. To determine the size of rivets suitable for the gauge of plate being joined, the general rule is for the rivet diameter to be equal to the plate thickness plus 0·08 inch.

Estimating Number of Rivets.—Rivets are usually supplied by weight, and to estimate the number of aluminium rivets per lb. the following formulæ may be employed:

$$\text{(1) Countersunk Rivets } (n) = \frac{1}{0{\cdot}0255d^2(2d + 3l)},$$

$$\text{(2) Round-head Rivets } (n) = \frac{1}{0{\cdot}0255d^2(3{\cdot}4d + 3l)};$$

$$\text{(3) Flat-head Rivets } (n) = \frac{1}{0{\cdot}0255d^2(5{\cdot}04d + 3l)},$$

where (n) denotes the number of rivets per lb. (d) is the rivet diameter and (l) is the length. In the case of countersunk rivets (l) represents the overall length including the head, but for round-head and flat-head rivets (b) represents only that part of the rivet below the head

The Hammer-drive Screw.—A handy alternative to riveting is provided by the hammer-drive types of screw (Fig. 73). These are hardened, and designed to cut a spiral groove in the plates as they are driven in by hammer. Because of the scientific design of the grooves, the metal closes in on the body of the screw, thus preventing it from working loose. The holes are pre-drilled to the special size specified by the manufacturer.

Considerable advances have been made with this type of fastening,

which can be used with confidence for joining iron, brass, steel, aluminium, bakelite, and compositions. They are available in various finishes such as brass, nickel plate, copper, galvanised, cadmium, and chromium plate. It should be noted that they are suitable only for fastening parts together, not for making a sealed joint ; this also applies to spun rivets.

RIVETING SYSTEMS

Rivet Spinning.—This is a process by which the shank of the metal rivet is caused to flow over, forming a head by a combination of pressure and rotary movement, instead of hammering. It is a simple process and practically noiseless. A special advantage lies in the fact that it is possible to regulate the degree of tightness when fastening two parts together

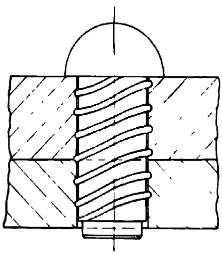


Fig. 73. A hammer drive screw suitable for fastening together light alloy sheet parts

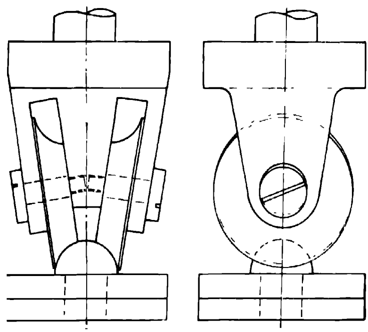


Fig. 74.—A simple tool for spinning over the ends of rivets

which may be designed to have a certain amount of movement in service, as, for instance, in the case of the lamp-shade carrier mentioned in Vol. III, Chapter 10.

Special rivet-spinning machines are designed and produced by various firms in this country and abroad. Many smaller firms, however, adapt ordinary pillar-type drilling machines by fitting a spinning head, the shank of which is inserted in the machine spindle. The most usual design consists of two wheels which revolve at the same time as the head in which they are mounted, and by applying normal hand pressure the metal is caused to flow over, forming a round head without the need for any further operation.

As a rule, round-head rivets are used, the head being supported on the underside by an anvil or block having a depression to accommodate the head. When pressure is applied the rivet does not revolve, the action being one of tangential rolling. The design of a spinning head is illustrated

in Fig. 74. Various modifications are to be found in the tools made by different firms. For instance, one (Fig. 75) consists of three hardened-steel balls inserted in a soft-steel housing to a little over one-half their depth, the edges of the holes in which the balls revolve being " peened over " to retain them.

The Chobert System.—The Chobert system of riveting (Fig. 76), marketed by Aviation Developments, Ltd., possesses the important advantage that it can be employed in cases where only one side of the job is accessible. The basic theory consists of expanding special hollow rivets until they fit tightly in the hole. This is achieved by using an internal mandrel which, when withdrawn, forces the rivet to "swell" into irregular and oversize holes, resulting in a tight fastening. If additional strength or water tightness is required the rivets can be " pinned," this giving, in effect, a solid rivet. No special training is necessary, the operation being performed with an automatic "gun," either manually or pneumatically operated. It is claimed that 1,000 to 1,500 rivets can be inserted and riveted per hour without undue effort. For further information, reference should be made to Vol. I, page 255.

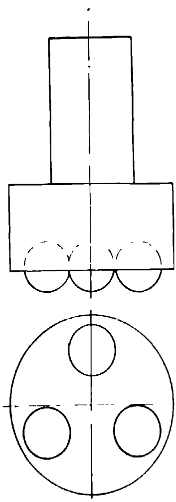


Fig. 75 - An improvised spinning tool incorporating three steel balls

Pneumatic Riveting.—Extensive use is made of pneumatic or air-operated hammers for closing over rivet heads. These are available in a variety of sizes and styles, but all are designed to deliver just the right weight of blow at the correct speed to give—without setting up stresses either in the rivet or in the metal skin—the impact necessary to close the head. The salient features of one well-known make of pneumatic riveting hammer is given in Fig. 77.

The Erco System.—This is another method of riveting in which punching and riveting is effected by a special machine which punches the hole and automatically feeds and heads the rivets—either countersunk or flush-head types—without moving the work between the punching and riveting strokes of the driving plunger. The holes are made with a punch and die, the punch remaining in the hole until the rivet is automatically inserted, thus avoiding the possibility of the material moving out of position.

By depressing the left foot pedal the die is aligned with the punch and the driving plunger carries the die to the work, punching the hole. During the punching stroke a rivet is automatically fed into the split-rivet shoe. Upon depressing the right foot pedal the rivet is aligned with the

punched hole, the driving plunger carrying the rivet downwards through the rivet shoe.

When the point of the rivet touches the punch, this punch is pushed out of the work, allowing the rivet to enter the hole. As the punch

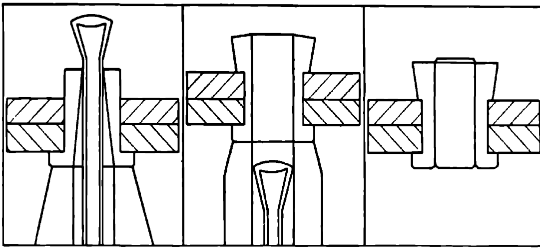


Fig 76.—The Chobert system of riveting, showing the rivet as the mandrel is placed in position, and the rivet tight and expanded after withdrawal of the mandrel The solid nature of the rivet when it is pinned may be seen from the end illustration.

recedes downwards the end-surface of the punch becomes part of the heading anvil.

Rivets for Location.—When hand riveting, it often happens that rivets can be made to serve the dual purpose of both dowels and rivets, *i.e.* to

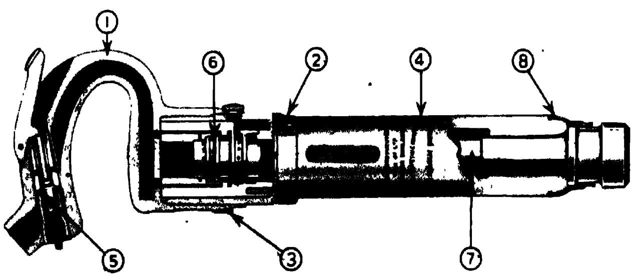


Fig 77.—A light C.P.T. pneumatic riveting tool. Key (1), handle, (2), exhaust deflector, (3), locking ring, (4), steel cylinder; (5), throttle valve, (6), cylindrical valve, (7), piston and, (8), snap retainer. (Courtesy of Consolidated Pneumatic Tool Co, Ltd.)

fasten together and also locate two separate parts. If so, certain precautions must be taken. The holes must be drilled smaller than the rivet shank, and the rivets (which probably have a slight "flash" of excess metal) should be filed or machined in a lathe to fit the holes. Care must

be exercised when hammering the rivet to keep it perfectly upright and to apply equal pressure on all sides. A few good heavy blows with a ball-pane hammer are preferable to a series of light blows which would have a tendency to harden the metal, especially steel.

AIRCRAFT RIVETING

In spite of the increased use of electric resistance welding in the aircraft industry, riveting still remains a manufacturing process of major importance. As with all other operations connected with the production of aircraft, the Industry has made considerable research to determine the best techniques, equipment, materials, etc., and a very useful survey of modern aircraft-riveting practice is contained in a Paper delivered by Mr. H. Giddings, A.F.R.Ae.S., A.M.I.Mech.E. (Chief Aircraft Technician, Bristol Aeroplane Co. Ltd.) to the Royal Aeronautical Society, and published in their Journal. By the kind permission of the Royal Aeronautical Society, the relevant portions of this Paper are reproduced below.

Function of Riveted Joints.—The main function of the aircraft riveted joint is a structural one, *i.e.* the transmission of load from one structural element to another. In carrying out this primary function the joint often has to satisfy subsidiary requirements; it has to provide a satisfactory aero-dynamic, weather, pressurisation or fuel seal, and also to provide an acceptable finish in relation to aero-dynamic or æsthetic standards.

It is obvious that the continuing trend of larger, faster, higher flying, and more efficient aircraft, means increasing severity in the above requirements because they mean higher loads, and stronger and thicker materials to be joined. Efficiency may mean laminar flow surfaces with very high standards of smoothness, equally necessary when high subsonic or supersonic speeds are involved. High altitude means pressurisation with resulting structural and sealing demands upon the riveted joints. A number of factors have combined to make the use of integral fuel tanks fashionable, again with resulting demands upon sealing.

The riveted joint may have to provide continuity in a member carrying tensile, compressive, or shear loads, usually only in the plane normal to the rivet axis. From the point of view of the rivet, all have the same actions, *i.e.* shear and bearing, and the usual loading parameter is taken as the load per inch length of the joint (P lb./inch). If the material is fully stressed to an allowable f lb./inch^2 and a plate thickness of t inch, then: $P = ft$.

With modern aluminium-alloy materials, ultimate tensile stresses as high as 70,000 lb./inch^2 may be used from purely static considerations, and the limit has probably not yet been reached. Sheet thickness of $\frac{3}{16}$ inch are already in fairly common use, and there are new projects necessitating thicknesses of double this amount. Thus joints in aluminium-alloy sheet materials are already requiring strengths in excess of 20,000 lb./inch.

Materials to be Joined.—Steel as an aircraft structural material is not

popular nowadays and its use is confined mainly to small fittings. At the present time aluminium alloys are almost universally favoured for primary structures, and the only prospect of immediate challenge comes from the new high-strength magnesium-zirconium alloys. Riveting problems, therefore, are almost entirely confined to the following aluminium-alloy materials :

Specification	*Ultimate Tensional Strength lb./inch²*
D.T.D. 610	56,000
D.T.D. 546	60,480
D.T.D. 687	72,000

The variants of these, unclad and close tolerance versions, give slightly better properties but not significantly different from our point of view. For comparison, the magnesium-zirconium figures are as follows :

D.T.D. 626	38,000

The present range of thicknesses of aluminium-alloy sheet in use is from 30 s.w.g. (0·012 inch) to about $\frac{3}{16}$ inch, but the next generation of aircraft will probably see this upper limit doubled.

Rivet Materials.—The basic problem in a rivet material is to achieve maximum possible strength with the greatest ease of setting. Unfortunately, these properties are directly coupled, hardness and setting difficulty increasing with increasing strength.

Thus the ratio

$$\frac{\text{Ultimate stress T/in.}^2}{\text{Vickers Pyramid Hardness No.}}$$

is approximately constant for most materials, its values being approximately :

Mild Steel	0·21
Aluminium Alloys	0·19

The other criterion of setting suitability, *i.e.* permissible elongation, also tends to be reduced with increasing strength, in both aluminium-alloy and steel materials. In general, steel materials show a slight advantage from both points of view.

For riveting efficiency, a rivet material of at least equivalent strength properties to the sheet material is required. Aluminium-alloy materials usually derive their strength from a combination of a solution heat-treatment and artificial or natural " ageing " process. The strongest sheet materials (*D.T.D.* 546 and *D.T.D.* 687 types) derive their strength from both solution treatment and artificial ageing. Unfortunately, equivalent rivet materials cannot be set in the fully aged condition. Obviously, therefore, unless artificial ageing of the rivets is resorted to after setting, the equivalent rivet materials to these alloys will not develop the same strength.

The strength of an aluminium-rivet material in the full naturally aged

condition therefore is all that can be obtained. This involves setting at a very early stage in the ageing process, otherwise setting difficulties, including cracking, occur.

The table on page 74 shows the principal aluminium-alloy rivet materials in order of increasing strength. L.36 is the almost pure-aluminium rivet, and may be dismissed from the structural point of view. *D.T.D.* 303 is the 5% magnesium alloy Mg.5 of relatively low strength and is set "as received." It is fairly popular in the low-strength field and is also recommended for use in magnesium-alloy structures. Its electrical potential is satisfactorily nearer that of magnesium than other rivet materials, and tropical corrosion tests have shown it to be satisfactory.

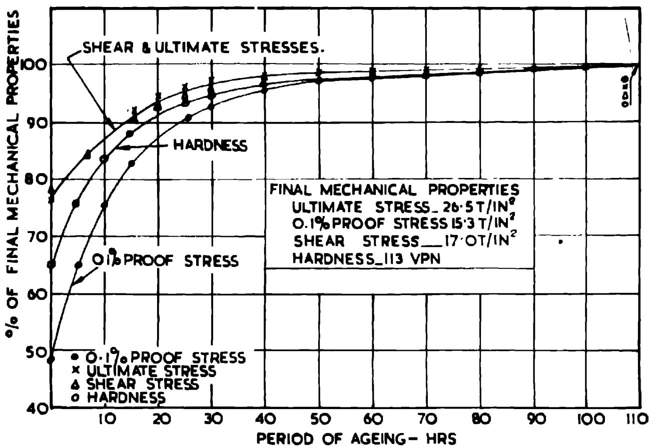


Fig. 78.—Age-hardening curves for L.37 aluminium alloy rivet material

D.T.D. 327 is the universally popular 2% copper-type alloy similar to the American 16-ST. It is solutionised in bulk before delivery and may be set satisfactorily in the full, naturally aged, condition. Shear strength is moderate, developing about 32,000 lb./inch² as riveted, and bearing strength is equal to that of *D.T.D.* 610-type sheet material.

The most popular high-strength rivet alloy is the straight Dural 17-ST type of L.37 specification. There is a production complication in that it has to be set in the freshly solutionised condition, before naturally ageing, as in the latter condition it is too hard to rivet. Fig. 78 shows the naturally ageing characteristics, and the usual requirement is to set within two hours of quenching. The onset of age-hardening can be delayed by refrigeration ; for example, if rivets are stored at 0° — 5° C., they may be

used up to 45 hours, or if at $-15°$ to $-20°$ C. up to 150 hours after quenching, but they must still be set within two hours of emergence from cold storage. Set under these conditions and after the full natural ageing period, bearing strength is adequate for use in *D.T.D.* 546-type sheet, and shear strength as riveted is approximately 36,000 lb./inch².

D.T.D. 404 is the 7% magnesium alloy Mg. 7, and has high strength derived from cold work, but is suspect in that it is prone to cracking. Experiments have been made with the very high-strength complex Zn-Cu-Mg alloys of *D.T.D.* 683 and *D.T.D.* 363 compositions, corresponding to the American types M.75S and C.77S respectively. The hope was that there might be a small bonus of strength to be utilised in the full naturally aged condition, the rivet being set freshly solutionised on a similar sort of basis to that already described for the L.37 material. After tests, however, the conclusion was that the small gain in strength was not worth the difficulty of setting such hard materials. The artificial ageing process is needed to achieve the full potentialities of the materials, and this is impracticable for most riveted structures.

Rivet Manufacturing Processes.—Rivets are manufactured from drawn or extruded wire or bar, and in the case of some tubular rivets, from sheet materials, by forging or machining, or in the latter case by pressing processes. Rivets made from drawn wire usually give better results than those from extruded bar or wire used, in some cases, for the larger-diameter rivets. The latter material is apt to have much coarser grain structure and increased liability to splitting, as well as lower strength, than the drawn wire.

The forged rivet ideally gives better grain flow than the machined type and may be preferred. In practice, machined rivets give satisfactory results, although they are more expensive than the former. Close tolerance countersunk-head rivets are difficult to produce by forging, but a recently developed compromise first of all forges the rivet and then machines the head only. Tolerances are satisfactory and the reduction in cost is significant.

Types of Rivet and Setting Processes.—Rivets may be conveniently classified as solid, semi-tubular, and tubular types. Within each of these groups are the different types of preformed head, of which the principal ones are the mushroom, snap, and countersunk varieties. The rivets are set in drilled or punched holes, which for structural or sealing purposes at least, should be controlled to reasonably close limits. For the countersunk-head types the hole may be cut countersunk up to a D/t ratio of about 2½ for the 120° head. Above this ratio the countersink should be formed by dimpling.

Sheet Preparation.—Holes are normally drilled and, because of the expansion of most rivets in the setting operation, tight tolerances are not necessary. For structural joints some control is desirable, and it is the practice of the Bristol Aeroplane Company to use a " controlled tolerance " hole achieved by the simple process of drilling slightly under size and then drilling out exactly to size with a final skimming operation.

Where a good flush finish is required it is important that the axis of the hole be "normal" to the sheet face, and a drill guide is used if the sheet is thick. The countersink is very important, both from the point of view of depth and angle, and also in getting the axis normal to the sheet face. It is desirable to use specially ground and set cut-countersinking attachments driven by the usual power tools, which control all these features.

Where dimpling is required, two classes of finish are provided, *i.e.* the normal-tolerance dimple, and the close-tolerance variety. The former is satisfactory from the strength point of view, is used with normal-tolerance rivets, and is formed by simple punch and die in any " squeezer." The finish is poor, particularly with high-strength sheet. The close-tolerance dimple is associated with the close-tolerance rivet and is only used where a high standard of flush finish is required, *e.g.* on wing skins forward of the rear spar. Considerable investigation has been made into the production of this class of dimple and two methods have been developed:

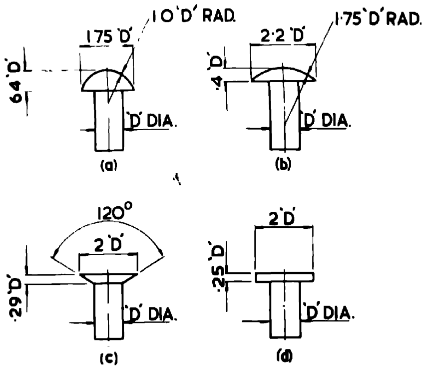


Fig. 79.—The proportion of standard solid rivets. (*a*), snap head, (*b*), mushroom head, (*c*), countersunk head, and (*d*), flat head.

(*a*) "Hot dimpling" by electrical resistance-heating of the sheet locally, using a converted spot-welding machine. Male and female bronze dies are screwed into the electrode stalks, and the ordinary heat and pressure cycle of the spot-welder, suitably modified, is applied to the sheet. The same scrupulous cleanliness as for successful spot-welding is required and only a full chrome-sulphuric acid or hydro-fluosilicic pickle will achieve it. Constant attention to dies to minimise pick-up and wear is also necessary.

(*b*) " Spin dimpling," again using male and female solid Stellite dies and pressure on the sheet. In this case the male die consists of a two-bladed revolving coining tool which spins the sheet into the female die. There is no cutting action and a light machine-oil is used as a lubricant. The heat generated by friction is very small and the process is essentially a cold-forming one. Special power-operated machines have been developed to carry out this process in production.

Both of these processes produce accurate dimples in high-strength sheet which are indistinguishable externally from a good cut countersink.

Metallurgical and structural fatigue tests to check these aspects of the dimples have been made with satisfactory results. In production, however, the spin-dimpling method is to be preferred, and is now in general use.

Solid Rivets.—The standard S.B.A.C. range covers these in all the normal materials and head shapes, with normal rivet tolerances, and also in the " close tolerance " type. Fig. 79 shows the standard proportions. The maximum size of aluminium-alloy rivets in general use is ½-inch diameter, although rivets up to ⅝-inch diameter have been used : however, these are exceedingly difficult to set. The majority of primary structural joints employ solid rivets, and in these days of flush finishes, mostly the countersunk-type head. The normal-tolerance rivet is satisfactory from the structural point of view, but when good finish is required then the close-tolerance rivet is used.

A comparatively recent innovation is the " domed countersunk "-type head. This is a normally proportioned countersunk head with the addition of a very slight dome which increases the efficiency of driving, at the same time minimising damage to the skin. The countersunk-head rivet also exists in a variety of included head angles between 60° and 120°.

The smaller angle heads generally cause less skin distortion in setting, and also pay a slight dividend in strength With most British firms the 120° head has been standardised, but American standard practice is to use the 100° type.

There is, however, at present a move in Great Britain to adopt the 100° head in order to fall in line with America. In the interests of standardisation again, in addition to the 120° countersunk head, the larger firms use the snap head on internal structures and the mushroom head on external surfaces where a flush finish is not required.

The tails of the rivets are set flat in the interest of setting speed, and tests have been made to determine the minimum protrusion required. This length has to be kept down, not only to minimise the amount of driving necessary and therefore improve finish and reduce cost, but also to keep the rivet weight at a minimum. Tests determined two things : (1) that the tail should be set to a diameter of at least 3/2 D. in order to achieve maximum shear strength, and (2) that an initial protrusion length of 1¼ D. set to the above diameter is all that is necessary to develop the full tensile strength of the rivet.

Setting Solid Rivets.—Methods of setting ordinary solid rivets are at present very varied, ranging from the primitive hand-held hammer and dolly to completely automatic machine setting. In the final assembly jigs the conventional pneumatic hammer and hand-held dolly are still widely used, and even the hand hammer in a few awkward places. In the interests of finish the " percussion " method, where the tail is hit by the hammer, is preferred to the " reaction " method where the preformed head is struck and the tail formed by the dolly.

Wherever possible, squeeze riveting is preferred to the foregoing because such methods give more consistent and better results, both in terms of

finish and strength, and also time and cost. By such means the setting force is accurately controlled, and the whole force is reacted by the machine and not partially by the structure, as with percussion or reaction riveting.

Many types of squeeze riveter are in use: pneumatic or hydraulic "alligator"-type tools, and also mechanical lever presses are to be found on the benches, whilst for large sub-assemblies special pneumatically operated squeezers are employed.

A useful American machine is the "Erco" fully automatic squeezer. This may be arranged to do anything from simple squeeze setting of a normally drilled and hand-fed rivet to automatically punching the hole, feeding the rivet, and setting, this including dimpling of the sheet in the

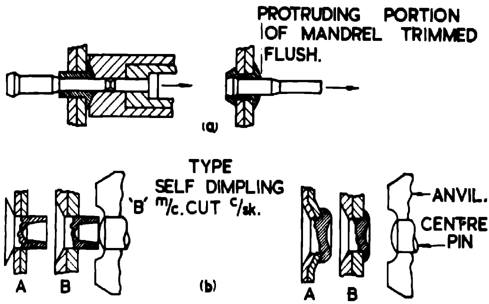


Fig. 80.—Illustrating the (a), Cherry-Avdel, and (b), bifurcated rivet processes.

case of countersunk rivets. This machine takes any standard-type rivet, including those in L.37 material. A very satisfactory structural joint is obtained with strength slightly better than with normally set rivets.

The flush finish obtained with countersunk-head rivets, however, is not of the highest standard, but is satisfactory for low-speed aircraft and a not too critical æsthetic standard. Riveting speed is good, and this is the main advantage.

One important implication of machine riveting is the necessity of careful design so that details and sub-assemblies may be taken to the machines, and also are matched to the machine limitations. Considerable sub-division of structure is required and jigging must be arranged to suit the process. Application of machine riveting to a structure designed and jigged conventionally is difficult, and the results would hardly justify the effort.

Semi-tubular Riveting.—The only example of this type of riveting process which it is proposed to describe is the well-known "Bifurcated" process (Fig. 80). It will be noted that the tail of the rivet is bored out over the length protruding from the sheet face. The motive of this

tubular tail is to ease the setting operation, which is effected by a punch being forced into the bore of the tail, splaying the tube out and over against the sheet.

This rivet has been used in holes prepared in the normal way and the tail set by an ordinary pneumatic gun, with a special tool. Special automatic machines are usually employed, one of which feeds the rivet into the hole and sets it. It will also dimple the sheet for a countersunk-head rivet if required, all in one sequence of operations. A small portable version of this riveting machine, which may be held by hand and used in assembly jigs and so on, has also been developed. This operates on the " one shot " principle and needs a separately held dolly at the rivet tail. The rivets are available in aluminium L.36, mild steel, and aluminium alloy *D.T.D.* 327 materials, and in $\frac{3}{32}$-inch, $\frac{1}{8}$-inch, and $\frac{3}{16}$-inch diameters. The normal head shapes are all supplied, with the exception of the snap head.

Tubular Rivets.—All the tubular rivets which will be described are what are known as " mandrel " setting. A more common term is " blind " rivets, because access to only one side is needed for placing.

In all of the four types concerned a mandrel with a larger diameter " tulip " end is inserted in the bore of the rivet from the tail and pulled into the rivet.
This expands the tail of the rivet and clenches it against the sheet.

The two great advantages of this type of process are :

(*a*) Its use for blind riveting when access is only available on one side.

(*b*) The setting action is a self-reacted squeezing operation, a great advantage when riveting very light structures and a good finish is required. Because of this, riveting of this type is used as a portable squeeze-riveting process in the assembly jig, not necessarily only when access is prohibited on one side.

(1) *The " Chobert " Process.*—This type of rivet is available in aluminium alloys to *D.T.D.* 327 and L.37, and in steel. Sizes range from $\frac{1}{8}$-inch to $\frac{3}{8}$-inch diameter, with snap or countersunk heads. The rivet is manufactured by machining and the process necessitates close tolerances. The bore is tapered, being slightly smaller in diameter at the tail, and the rivet is set by drawing a high-tensile steel mandrel completely through the bore. If sealing or maximum strength is required, a sealing pin is inserted in the bore after setting.

Special guns are available for setting, in manually, pneumatically, or pneumo-hydraulically operated types. For production purposes repeater-type guns are used, these storing up to approximately 50 rivets on the mandrel ; when empty the mandrel may be instantaneously recharged from the special " cartridges " of rivets supplied. When sealing pins are fitted the ultimate strength is nearly as good as solid rivets, but the Proof Strength is not so good. This is principally due to the poor clenching action and consequent tilting of the rivet under load.

If mandrels are allowed to wear, difficulty is sometimes experienced with poor expansion of the rivet in the hole. Another snag is associated with the sealing pins, *i.e.* damage is often caused to light structures by their insertion, and a trimming operation is sometimes necessary when complete insertion of the sealing pin cannot be achieved.

Despite these drawbacks the Chobert rivet is widely used, and while it is not by any means a cheap rivet, its speed in setting is good, particularly if sealing pins are not required.

(2) *The "Avdel" Riveting Process.*—The "Avdel" rivet was developed initially by the Bristol Aeroplane Company and is now manufactured by Aviation Developments Ltd., who also supply specialised setting equipment. It is shown in Fig. 80. Unlike the "Chobert" system a separate mandrel is supplied with each rivet, being retained in the rivet as a seal after setting. The mandrel has three diameters, the smallest being a loose fit in the bore of the rivet. The intermediate diameter is an interference fit in the rivet bore, while the largest diameter on the end is of such a size that it expands and clenches the tail of the rivet against the sheet. The small end of the mandrel is of sufficient length to be gripped by the setting tool which first draws the intermediate diameter into the rivet, thus expanding the shank tightly into the hole As the mandrel is further drawn into the rivet, the large diameter clenches the tail on to the sheet. Finally, the mandrel breaks at a notch between the small and intermediate diameters when the required setting load is reached. The protruding part of the mandrel is trimmed, either by simple side cutters or by a rivet-milling tool.

It will be noted that the system is designed to give both rivet expansion and drawing together of the sheets. The latter action is limited somewhat because the rivet is expanded to a tight fit in the hole before clenching takes place. Good clenching is, nevertheless, obtained, together with excellent strength, sealing, and finish.

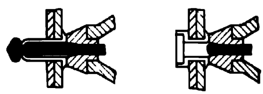
The rivet is available in aluminium alloy *D.T.D.* 327 material and with snap or countersunk heads, and development is proceeding to produce the rivet in A.17ST-type aluminium alloy. The mandrel is also made from aluminium alloy, but to *D.T.D.* 363. This rivet is particularly useful as a portable squeeze-riveting process in very light structures, where a tight rivet with good Proof Strength and fatigue resistance has to be associated with a fine finish. For the latter requirement the countersunk head of the rivet is set slightly "proud" and then milled off, the rivets then being almost indistinguishable from the sheet. Unfortunately, it is an expensive process, and its use has to be restricted to those applications where its special virtues are needed.

(3) *"Cherry" Rivets.*—These rivets are of American manufacture and widely used in that country, although the range generally corresponds to various British rivets. Thus the "self-plugging" type corresponds to the "Avdel," and the "pull through" type corresponds to the "Chobert." There is a third type known as the "regular hollow" type which is similar

to the British " pop " rivet. The rivets are available in steel, aluminium alloy, and Monel, in both countersunk and brazier-type heads, and in a size ranging from $\frac{1}{8}$ inch to $\frac{9}{32}$ inch. The A.17ST and steel self-plugging types are extremely useful rivets and show an advantage over the *D.T.D.* 327 Avdel rivet.

(4) *" Pop " Riveting.*—This system is shown in Fig. 81: hand- and power-operated setting equipment is available. The mandrel is a loose fit in the bore of the rivet and the larger diameter head expands the tail when drawn into it. Tail formation and the sheet-clenching action are good, but rivet expansion in the hole is poor.

The mandrels can be supplied to break either adjacent to the head (Break-head type) or in the stem within the rivet (Break-stem type). With the former type the heads of the mandrels fall clear, leaving a hollow rivet, while in the latter case the mandrel is usually retained in the rivet and gives some degree of sealing. Unfortunately, little increase in strength is achieved and a small percentage of the mandrels fall out, either immediately after setting, or during service. The rivets are available in aluminium alloy (*D.T.D.* 303 equivalent) and Monel materials, in sizes from $\frac{7}{64}$-inch to 0·2-inch diameter, and in both snap- and countersunk-type heads. This rivet is excellent where strength and sealing requirements are not too rigorous, and is very economical and quick in setting. It is very popular, and is widely used in industry outside that of aircraft manufacture.



(a)

(b)

Fig. 81.—The " pop " riveting process using (*a*), the break-head mandrel, and (*b*), the break-stem mandrel.

Rivet Milling.—Demands for a super finish have led to the development of tools for milling rivet heads flush after setting. One such tool consists of a special end-mill attachment for a standard Desoutter pneumatic drill gun, provision being made for accurate setting for depth of cut; an air jet removes the swarf, and there is a rubber pressure-pad with hardened-metal guide bush. Where a milled finish is consistently required, adjustment has to be made to the depth of countersink so that the head of the rivet is slightly proud of the skin surface.

Rivet Weights.—A few figures about aluminium-alloy rivets in the Brabazon (Vol. III, Fig. 215) may be of interest. There are approximately two million rivets in the aircraft, the largest being $\frac{3}{8}$-inch diameter. All external surfaces are flush riveted with the exception of the fuselage, the gross surface area being approximately 22,000 feet². Considering, in this instance, only the weight of the heads and tails, typical weights of the rivets are as follows: $\frac{1}{8}$-inch diameter countersunk head=0·0016 lb. per rivet, and $\frac{1}{8}$-inch diameter mushroom head=0·0029 lb. per rivet.

There is thus an appreciable weight saving by using the countersunk rivet. The total weight of rivet heads and tails on the Brabazon is approximately 1 ton, and if the fuselage were flush riveted by cut-countersunk methods, the saving would be approximately 250 lb.

It is obvious that on a large aircraft such as this the penalty of using steel rivets or bolts would be considerable. From strength considerations it might be considered on the inner-wing main-box structure, but the weight penalty would probably be in the region of 1,000 lb., or possibly more.

ALUMINIUM ALLOY RIVET MATERIALS

Spec. No.	Material: Comml. Name	Material: Alloy Type	Min. Spec. ft Tons/in²	Ult. Shear Stress Tons/in²	Heat-treatment Condition: When Placed	Heat-treatment Condition: Ultimately
L.36	Noral 2S	98% Al	7	4.8	As received	As received
DTD 303	MG5	4½–5½% Mg	16–21	12.8	As received	As received
DTD 327	Noral 16ST	1½–3% Cu	17	14.8	Solutionised and naturally aged	Solutionised and naturally aged
L.37	Noral 17ST	3½–4½% Cu	25	16.2	Freshly solutionised	Solutionised and naturally aged
DTD 404	MG7	6½–10% Mg	27	17.5	As received	As received
DTD 683 alloy	M 75S	Complex, medium Zn–Cu–Mg content	25	15.6	Freshly solutionised	Solutionised and naturally aged
			29	18.5		Solutionised and aged at 100° C for 24 hours
DTD 363 alloy	C 77S	Complex, high Zn–Cu–Mg content	20	17.8	Freshly solutionised	Solutionised and naturally aged
			34	21.2		Solutionised and aged at 100° C, 24 hours

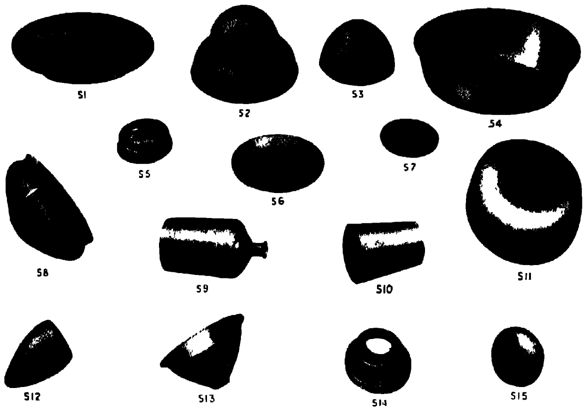
CHAPTER 6

METAL SPINNING

METAL spinning is a process whereby articles are produced from sheet-metal: they are usually circular in one plane, but in a direction at right angles to the plane of rotation may follow any fancy or ornamental designs. The illustration (Fig. 82) (reproduced by the courtesy of Messrs. Charles Taylor, Ltd., Birmingham, as also are Fig. 86 and Figs. 90 to 94) serves to give some idea of what can be produced by the metal-spinning process, and it shows that elliptical or oval as well as circular forms can be obtained by this process.

Spinning Lathes.—Special spinning lathes are manufactured by various makers for this class of work, the general design following closely that of the ordinary lathe which is familiar to every engineer. There are, however, several necessary and important differences. A considerable stress takes place in a direction along the axis of the lathe headstock during the operation of spinning, as will be appreciated later when a detailed description of the process proper is given. The headstock and the spindle must, therefore, be very sturdily built, and provision must be made in the design of the spindle and its bearings, particularly the latter, so that the lateral pressure can be withstood. A heavy ball-thrust washer is usually incorporated in the design immediately at the forward end of the spindle, and in some makes a further thrust washer is fitted to the other bearing also. Usually the drive is applied through a three- or four-step cone pulley, and the speeds at which the lathe is driven vary between 500 and 2,000 revolutions per minute, according to the class of metal being worked and its diameter. It will be appreciated that the bigger the diameter, the greater the surface speed for an equal number of revolutions in a given time. There are variations in the design of spindle noses, the two most frequently employed being shown in Fig. 83. Both are externally threaded, and at A the spindle is bored to a " Morse " taper, whilst at B a parallel tapped hole is shown. No material difference arises whichever is employed, but the chucks or appliances are necessarily designed according to the type of spindle in the lathe being used.

The Headstock.—Continuing the comparison between the two types of lathe, in the process of spinning, the sheet-metal plate from which the article is to be fashioned is driven, not by a lathe dog, nor by being held in the headstock chuck, but is held by friction between what is termed the former and the follower. The former is a piece of solid material



DESCRIPTION AND DIMENSIONS

No	Description	Material.	Approximate Dimensions
S 1	Oval Entrée Dish	Copper	11¾ and 9½ inches diam. × 1¼ inches deep
S 2	Electric Shade	Brass	8½ inches diameter × 5 inches deep
S 3	Motor-cycle Headlight Body	Brass	6 inches diameter × 3½ inches deep
S 4	Oval Deep Dish . .	Copper	12½ and 10½ inches diam × 3½ inches deep
S 5	Kettle Lid . .	Aluminium	4 inches diameter
S 6	Plate .	Aluminium	6¼ inches diameter × ¾ inch deep
S 7	Electric Light Fitting .	Aluminium	4 inches diameter × 1 inch deep
S 8	Rose Bowl . . .	Brass	6½ inches diameter × 3½ inches deep
S 9	Flask (all one piece)	Aluminium	3¼ inches diameter × 6½ inches high
S 10	Drinking-cup	Aluminium	3¼ inches diameter × 4½ inches deep
S 11	Kettle Body	Aluminium	7 inches diameter × 4 inches deep
S 12	Motor Sidelight Body	Brass	2½ inches diameter × 3¾ inches deep
S 13	Cycle Reflector .	Copper	5 inches diameter × 2⅜ inches deep
S 14	Electrical Fitting	Copper	3⅝ inches diameter × 1½ inches deep
S 15	Motor Sidelight Body	Copper	2¾ inches diameter × 2¼ inches deep

Fig. 82.—Examples of work produced by the metal-spinning process.

shaped to the form to which the metal is to be moulded, which is solidly fixed to the headstock spindle and therefore turning with it, while the follower is a piece introduced between the job and the nose of the tail-stock spindle in the manner shown in Fig. 84. Pressure must be supplied of a sufficient amount to hold the former A, the work B, and the follower C so tightly that they will revolve as one, this pressure being applied by the tailstock handwheel D. It will be seen that were an ordinary lathe centre fitted to the tailstock, the friction, due to the pressure which has been applied, would be so great at the point E as to render the process impracticable at the rotating speed necessary. To overcome this

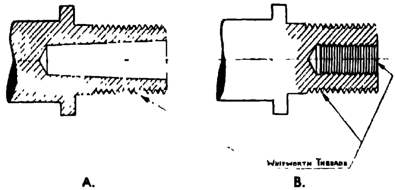


Fig. 83.—Spindle nose. Alternative types

difficulty, the obvious solution of making the tailstock centre also able to revolve is adopted, this being accomplished in the manner shown in Fig. 85. Here again, special attention must be paid to the great amount of end thrust which is unavoidable in metal spinning, and the "live centre," as it is called, is also provided with means of taking this end thrust without impairing its efficiency.

The Tailstock.—Due to the heat generated, and the effect of spinning on the molecular condition of the metal, it is necessary with certain metals that the work should be frequently annealed, and for this purpose the work must be removed from the lathe. While it would be possible to remove the work with the ordinary lathe tailstock in which the spindle or barrel is fed forward or backward by a screw and operated by a handwheel, it is a slow operation, and if, for example, a shell were being spun of several inches depth, quite an appreciable time would be taken in screwing back the barrel for this distance, and after annealing the work, rescrewing it back again. The special design employed in the tailstock of a spinning lathe, however, renders this a simple operation. A device similar to that of the quick-action bench vice is fitted so that when the screw is slackened back slightly the operating catch can be disengaged, which allows the tailstock spindle to slide with ease and rapidity in either direction. Such a tailstock is shown in Fig. 86. On one make of machine a foot pedal is employed for this quick release of the tailstock spindle, a pressure of the foot feeding the spindle rapidly forward, leaving both hands free to adjust the work, the movement of a simple lever finally locking it in position. On releasing the lever, a spring automatically withdraws the spindle. Fig. 87 shows the action diagrammatically, and the saving of time and effort will be apparent.

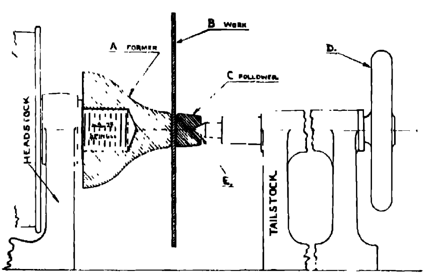


Fig. 84.—Mounting of disk in lathe

Hand Tools.—The features of spinning lathes so far described apply to all machines, whether for hand or

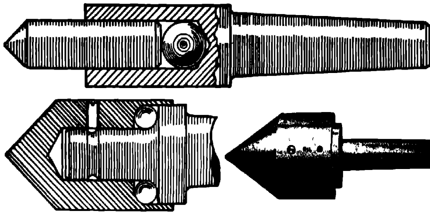


Fig 85.—" Live " tailstock centres.

mechanical operation. The hand process, which is most commonly used, except where mass production of a component in considerable quantities is contemplated, is performed by tools, similar to A in Fig. 88, which have their actual operating surfaces of special shapes according to the nature of the work, or part of the work, being done. A simple application of the principle of levers enables the necessary force to be applied to the working end of the tool, and from a glance, in Fig. 88, it will be seen that by moving the handle in the direction B against the fulcrum C a considerable pressure will be exerted on the work in direction D. The hand spinning lathe is, therefore, equipped with the fulcrum C, which takes the form of a vertical pin of steel sufficiently strong to withstand the pressure of the tool. As the work proceeds, the shell which is being spun may have assumed the shape shown dotted at E, and to get the best leverage to proceed with the work it is necessary to advance the position of the fulcrum pin C. The means by which this is done is extremely simple, as will be seen from Fig. 89, in which the pin C is shown to be of circular section and of two diameters, the length of B, which is the portion against which the spinning tool works, varying between 3 and 4 inches, while the part A, which is $1\frac{1}{2}$ to 2 inches long, is made a free fit in the holes provided in the lathe tool-rest shown at D. The location of the fulcrum point is varied as needed, by simply moving pin C to the hole most suitable to requirements. Two of the fulcrum pins C are necessary, as on some classes of work it is advisable to support the work against the pressure of the spinning tool, this being done by holding a back stick on the opposite side of the work, this stick being fulcrumed from a different pin. The tool-rest D is held in the lathe tool-rest holder in the usual way.

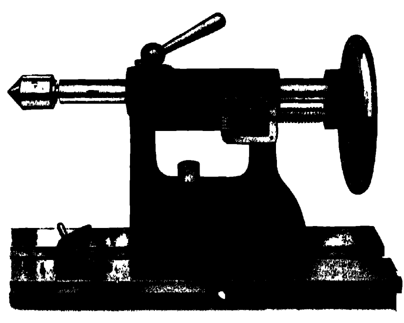


Fig. 86.—Spinning-lathe tailstock with sliding, quick-release spindle.

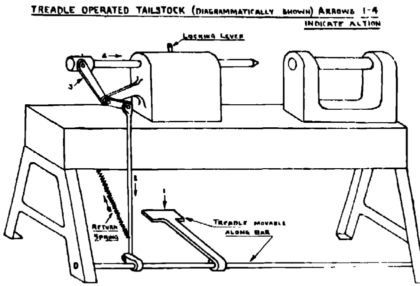


Fig. 87.—Quick-action arrangement to tailstock spindle

It will be seen from the foregoing description that for occasional use, where, as in the case of a small metal-workers' shop, the expense of a special lathe for spinning processes is not practicable, an ordinary lathe of strong proportions could be adapted by the inclusion in its equipment of a "live centre," the special tool-rest with fulcrum pins, and the necessary spinning tools; the chucks, etc., being made when wanted and according to the requirements of the job to be done. A typical hand spinning lathe is illustrated in Fig. 90

In mass-produced spun work, mechanical means to produce the article are generally applied, the method being usually to form the metal to the desired shape by revolving the sheet between rollers. In this class of work, these forming rollers are shaped according to the requirements of the component to be made, and care has to be taken in designing the set-up to make provision for the holding of the job itself. On a deep shell with a narrow mouth, the fixtures can become very complicated indeed. Typical jobs of this nature are considered later. In some instances, where an article is required in sufficiently large quantities, special machines are designed for its production, or even for performing one operation in its manufacture.

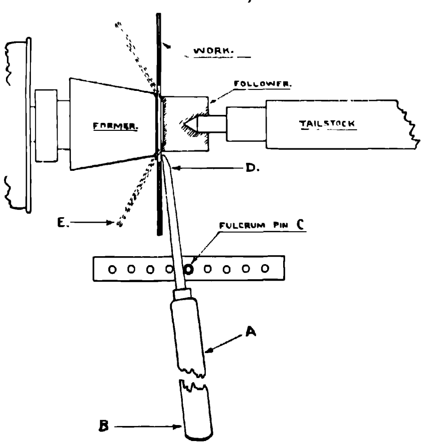


Fig. 88.—Action of hand spinning tool.

Trimming.—When spinning, as will be explained later, the shapes which are formed result in a compression or stretching of the metal of which the spun article is made, and it is not possible by mathematical or other means (except

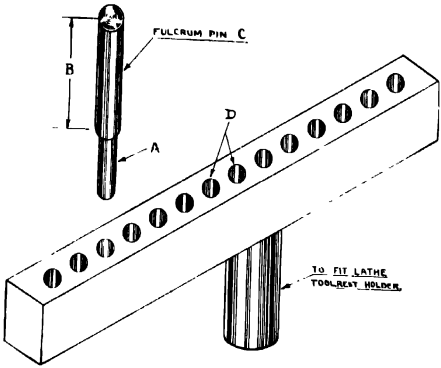


Fig. 89 —" T " rest and pin

in the simplest of designs) to determine exactly what size of metal disk will be required to produce the particular article. Experience will enable the operator to form an approximate idea, and, in any case, a disk of ample size to produce the article with a little to spare is employed. In the process of spinning a deep shell, it will be obvious that a considerable reduction in the outer diameter of the plate from which it is formed must arise, and the tendency of this reduction is to form wrinkles around the edge, and these, if not removed, will eventually develop into cracks. On a long and complicated job it is advisable that these wrinkles be removed, and for that purpose the process of trimming is employed. This consists of the removal of the outer edge of the disk, and some spinners, in the hand process, do this with an ordinary diamond-pointed lathe tool. Special machines are,

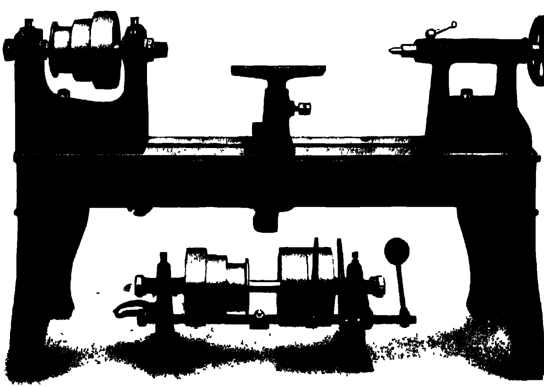


Fig 90 —Hand spinning lathe

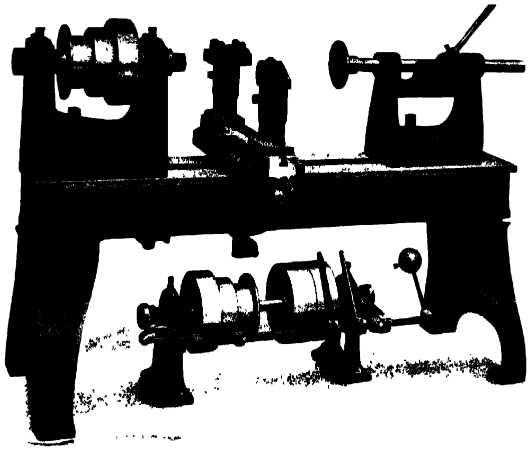


Fig. 91.—Lathe with trimming and beading attachment

however, made for this purpose, such a lathe being shown in Fig. 91. This lathe is also equipped with a beading appliance, by means of which, after trimming, the metal is rolled over at the edge, thus adding considerable strength, and at the same time making the article

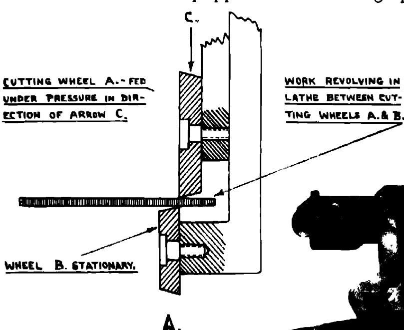
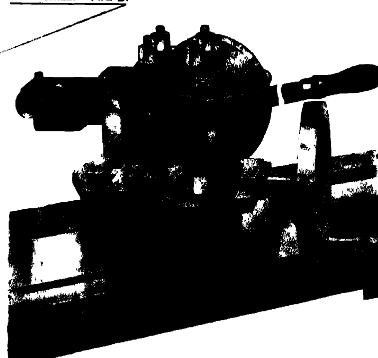
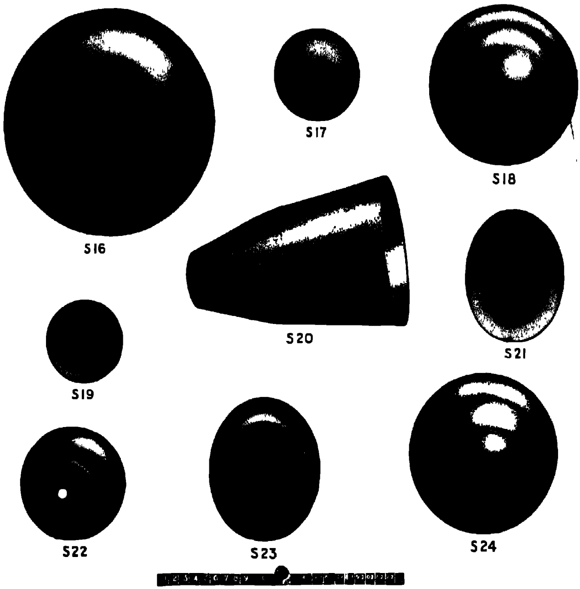


Fig 92.—Trimming slide Showing action of cutting wheels.



easy to handle. The trimming process is also used to remove any surplus metal from a completed job. For use on a hand spinning lathe an attachment shown in Fig. 92 is employed, the actual trimming operation being accomplished by the shearing action of two circular cutters operating one on either side of the metal, as shown at A, the rollers being fed together until the action has been completed



DESCRIPTION AND DIMENSIONS

		Material.	B W G	Approximate Dimensions.
S 16	Enamelled Bowl .	Steel	23	20 inches diameter × 7 inches deep
S 17	Motor-lamp Body	Brass	22	8½ inches diameter × 4¼ inches deep
S 18	Geyser Cover .	Aluminium	22	14¼ inches diameter × 5½ inches deep
S 19	Plate . . .	Steel	18	7 inches dameter × ⅞ inch deep
S 20	Aeroplane Cowling	Aluminium	9	12½ inches diameter × 20 inches long
S 21	Oval Entrée Dish	Copper	20	11¾ and 9¼ inches diam. × 1¼ inches deep
S 22	Motor-car Headlight	Brass	19	10 inches diameter × 5½ inches deep
S 23	Oval Deep Dish	Copper	20	12½ and 10½ inches diam × 3¼ inches deep
S 24	Geyser Cover	Brass	23	14 inches diameter × 6 inches deep

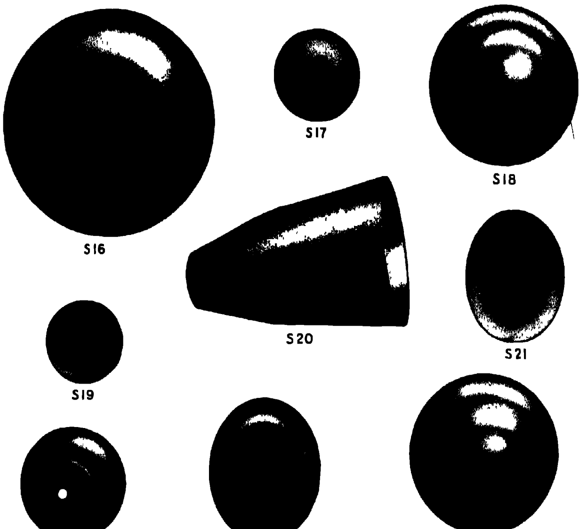
Fig. 93.—Further examples of spun work.

HAND TOOLS AND OPERATIONS

A study of the spun articles shown in Fig. 82, and the further selection in Fig. 93, will reveal the wide variety of shapes which it is possible to produce by this method of metal spinning. It will be seen from the descriptions given that brass, copper, aluminium, and steel are used, and the reader will be, no doubt, familiar with many of the domestic articles in tinplate, as well as pieces of jewellery in gold, silver, etc., which have been produced by this process. The dimensions of the articles which it is possible to produce by spinning range from, say, the very small dome cap of a salt-cellar to the cowl of an aeroplane engine, perhaps 5 feet in diameter and 1 foot 6 inches wide, the thickness of the metal worked in making these spun articles ranging from just over $\frac{1}{64}$ inch to almost $\frac{1}{32}$ inch. From these details the wide scope of the spinning process will be gathered. A set of tools for the hand spinner is shown in Fig. 94, all the faces which come into contact with the work being burnished and polished to a glass-like finish so that the work will not be marred by scratches. In use the tools are mounted in hardwood handles of about 15 inches in length, making the total length about 24 inches. This may seem to those unfamiliar with the spinning process to be an excessive size, but in practice, and on heavy work, tools 36 inches long are frequently used in order to obtain the necessary leverage. Great pressures are sometimes necessary in the application of these tools, and in practice this pressure is not merely a matter of the strength of the hands or arms, but the handle extends far enough to be held securely under the right armpit, the weight of the body being applied to provide additional force, the hands mainly directing the application of the tool to the work. Fig. 95 illustrates the method by which the tool is held. The tools of Fig. 94, while being a complete set for general work, by no means represent all that are used. Special ones are sometimes made to suit a particular job, or part of a job, but for all work of an ordinary nature those shown are generally sufficient.

Briefly, the uses of the tools illustrated are as follows. At E is shown the tool most commonly used, this being usually employed to start the spinning operation, and to bring the work roughly to the shape of the former. With tool F more detail can be added to the work, particularly in the finishing of curved portions. The fishtail tool D is used for smoothing down the work, its wide face helping in this, and it is also used for flaring out a job. Tool G is named the planisher, and its purpose is to smooth down the job, removing any tool-marks which may have been left by previous operations. The remaining tools, J, K, and L, are mostly used for internal work, the hook tool-rest A being used as a support and stop for these tools. The wheel tools shown at B and C provide the means of turning over the edge of a spun article to form a beaded edge, which adds both to the strength and the appearance of the job. The diamond-pointed tool H is also included in the equipment for the purpose

easy to handle. The trimming process is also used to remove any surplus metal from a completed job. For use on a hand spinning lathe an attachment shown in Fig. 92 is employed, the actual trimming operation being accomplished by the shearing action of two circular cutters operating one on either side of the metal, as shown at A, the rollers being fed together until the action has been completed



DESCRIPTION AND DIMENSIONS

No.	Description	Material.	B.W.G.	Approximate Dimensions.
S 16	Enamelled Bowl	Steel	23	20 inches diameter × 7 inches deep
S 17	Motor-lamp Body .	Brass	22	$8\frac{1}{4}$ inches diameter × $4\frac{1}{4}$ inches deep
S 18	Geyser Cover . .	Aluminium	22	$14\frac{1}{4}$ inches diameter × $5\frac{1}{2}$ inches deep
S 19	Plate	Steel	18	7 inches dameter × $\frac{7}{8}$ inch deep
S 20	Aeroplane Cowling .	Aluminium	9	$12\frac{1}{4}$ inches diameter × 20 inches long
S 21	Oval Entrée Dish	Copper	20	$11\frac{3}{4}$ and $9\frac{1}{4}$ inches diam × $1\frac{1}{4}$ inches deep
S 22	Motor-car Headlight .	Brass	19	10 inches diameter × $5\frac{1}{2}$ inches deep
S 23	Oval Deep Dish . . .	Copper	20	$12\frac{1}{2}$ and $10\frac{1}{2}$ inches diam × $3\frac{1}{2}$ inches deep
S 24	Geyser Cover .	Brass	23	14 inches diameter × 6 inches deep

Fig 93.—Further examples of spun work

HAND TOOLS AND OPERATIONS

A study of the spun articles shown in Fig. 82, and the further selection in Fig. 93, will reveal the wide variety of shapes which it is possible to produce by this method of metal spinning. It will be seen from the descriptions given that brass, copper, aluminium, and steel are used, and the reader will be, no doubt, familiar with many of the domestic articles in tinplate, as well as pieces of jewellery in gold, silver, etc., which have been produced by this process. The dimensions of the articles which it is possible to produce by spinning range from, say, the very small dome cap of a salt-cellar to the cowl of an aeroplane engine, perhaps 5 feet in diameter and 1 foot 6 inches wide, the thickness of the metal worked in making these spun articles ranging from just over $\frac{1}{64}$ inch to almost $\frac{5}{32}$ inch. From these details the wide scope of the spinning process will be gathered A set of tools for the hand spinner is shown in Fig. 94, all the faces which come into contact with the work being burnished and polished to a glass-like finish so that the work will not be marred by scratches. In use the tools are mounted in hardwood handles of about 15 inches in length, making the total length about 24 inches. This may seem to those unfamiliar with the spinning process to be an excessive size, but in practice, and on heavy work, tools 36 inches long are frequently used in order to obtain the necessary leverage. Great pressures are sometimes necessary in the application of these tools, and in practice this pressure is not merely a matter of the strength of the hands or arms, but the handle extends far enough to be held securely under the right armpit, the weight of the body being applied to provide additional force, the hands mainly directing the application of the tool to the work. Fig. 95 illustrates the method by which the tool is held. The tools of Fig. 94, while being a complete set for general work, by no means represent all that are used. Special ones are sometimes made to suit a particular job, or part of a job, but for all work of an ordinary nature those shown are generally sufficient.

Briefly, the uses of the tools illustrated are as follows. At E is shown the tool most commonly used, this being usually employed to start the spinning operation, and to bring the work roughly to the shape of the former. With tool F more detail can be added to the work, particularly in the finishing of curved portions. The fishtail tool D is used for smoothing down the work, its wide face helping in this, and it is also used for flaring out a job. Tool G is named the planisher, and its purpose is to smooth down the job, removing any tool-marks which may have been left by previous operations. The remaining tools, J, K, and L, are mostly used for internal work, the hook tool-rest A being used as a support and stop for these tools. The wheel tools shown at B and C provide the means of turning over the edge of a spun article to form a beaded edge, which adds both to the strength and the appearance of the job. The diamond-pointed tool H is also included in the equipment for the purpose

of trimming the work to size, or skimming off any irregularities which may have been left by the use of other tools.

A pair of special pliers, with the noses of round section and similar in appearance to Fig. 96, will be found useful in turning over the edges of a job which has been slightly flared, partly forming a bead which is finished off with the wheel tool. Where great strength is required and a wired edge is to be added, they will be almost indispensable. The wire is placed in position and loosely secured by pressure from the pliers, the metal being spun round it with the beading tool.

The Spinning Process.—In order that a clear idea of the process may be obtained, Fig. 97 may now be studied. In this diagram is shown a simple chuck or former A, the sheet-metal disk B, which is to be spun to the shape of the chuck, and the follower C, which is free to revolve with the "live centre" as previously described, A, B, and C therefore revolving as a unit. The nose of the spinning tool is applied to the disk close to the point at which the first contour occurs, and, levering against the fulcrum pin D, pressure is applied to the tool, which will cause the disk to assume a partly conical shape, and the nose of the spinning tool will have travelled towards the circumference of the disk. This condition is indicated in the diagram by the first set of dotted lines. Repeating this process, the formation of the cone is advanced still more, say to the second dotted position, and so on until eventually the metal has been brought into close contact with the chuck or former, thus completing the spinning. That, then, is the theory. A number of practical considerations have, however, to be taken into account.

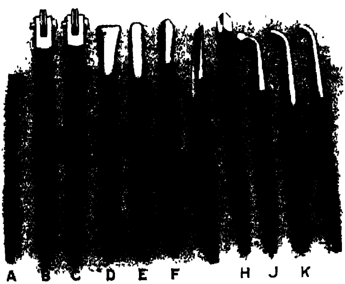


Fig. 94.—Hand spinning tools.

The same former and disk are diagrammatically shown in Fig. 98. The shaded portion of the disk B is equal in diameter to the flat end of the former, and this portion of the metal requires no treatment whatever for it to conform to the shape of the former. From this circumference, however, it is necessary to work the metal to bring it into its new shape, and taking a point about ½ inch along the edge of the former, referred to as diameter 1, it will be found that the circumference at this point is approximately 7¾ inches. Describing a circle on disk B ½ inch from the

edge of the shaded portion should give a line, which when spun would lie over diameter 1 on the former. The circumference of this circle 1 is, however, about $9\frac{1}{2}$ inches. Applying the same method to another point on the former at diameter 2, the circumference will be $12\frac{3}{4}$ inches, while, making allowance for spinning to diameter 1, the corresponding circle on the disk will only be about 12 inches in circumference. Similar changes occur at all points on the former, and it will be obvious that the very texture of the metal is changed. The metal disk has to be compressed to meet the former at diameter 1, whilst at diameter 2 it has to be stretched a matter of $\frac{3}{4}$ inch. This would mean that at diameter 1 all the surplus metal would be piled up and the shell unduly thickened, whilst at diameter 2 the shell would be reduced in thickness in order that the smaller diameter of the disk be made to encircle the larger diameter of the former.

Fig. 95.—Application of hand spinning tool

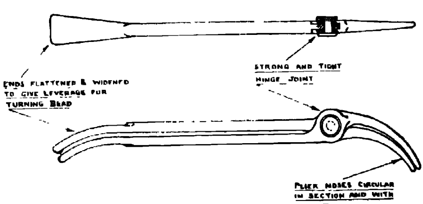


Fig. 96.—Spinners' pliers

It is here that the skill of the spinner is shown to the greatest degree. By careful manipulation of the spinning tools he can reduce the thickened parts, spreading the metal to the thinner portions by the pressure and movement of the spinning tool from centre to circumference of the sheet being spun, or the reverse way, either alternating

the movement or applying the tool in the same direction as necessity or the peculiarities of the particular job warrant. By this method it is possible to control the thickness of metal, even in a shell of widely varying diameters, so that were it split open lengthwise it would be found that very little difference of thickness was apparent throughout the entire section.

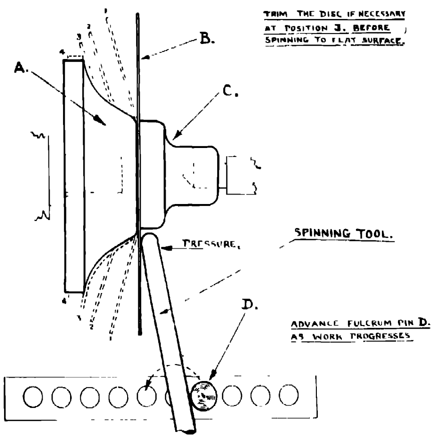


Fig. 97 Stages in simple spinning.

The process of moulding the metal to shape must be a gradual one. If too large a feed is applied, or more pressure is given than the job necessitates, or the feed is made in one direction only, difficulties will arise; it will be found that the disk will wrinkle and vibrate, and if the spinning process is continued, the disk will break at the point where the pressure of the spinning tool is applied. Cracks will also appear round the circumference of the disk and these will require trimming off before proceeding with the work. Holding the tool for too long a time in one position is also to be guarded against, as the effect of the work done by the tool is to harden the metal, and more frequent annealing will therefore be necessary.

When spinning metal disks of fairly large diameter, particularly when the shape of the former does not lend

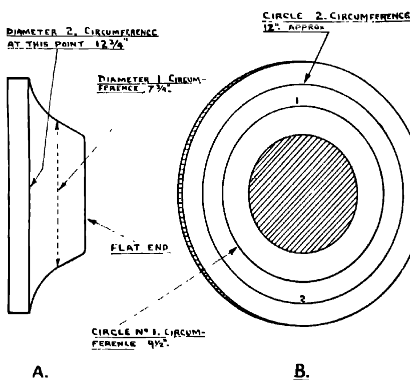


Fig. 98.—Former and disk.

any support to it, the use of a back stick, as it is called, is necessary. This takes the form of a hardwood stick of stout section about 14 inches long, the operating end being shaped as shown in Fig. 99, which also illustrates its application in the process of spinning. As will be seen, it is used in the same manner as the spinning tool, but on the opposite side of the disk. Pressure is applied in the direction indicated, and the work revolves between the back stick and the spinning tool, so that pressure of the latter is counterbalanced, thus preventing any fracture or buckling of the work. As the spinning-tool face moves along the work so does the back stick, it being always positioned immediately behind the tool and on the opposite side of the work. The fulcrum pins A and B are a loose yet rigid fit in the holes carrying them, and offer no frictional resistance, revolving as the tools are moved from and to the centre of the disk.

The speeds at which metal spinning by hand can be performed vary according to the class of metal being worked upon, its thickness, the diameter of the work to be performed, and the intricacy of the design. No positive data on this matter can, therefore, be given, but the operator, after gaining some experience, will be able by experiment to determine how the particular metal stock is behaving under the treatment employed, and raise or lower the speed accordingly. Generally speaking, the heavier the metal, the lower the spindle speed. As an example, sheet-iron of 20 b.w.g. can be readily spun at 600 revolutions per minute, but for the heavier gauges the speed may have to be reduced to as low as 400 r.p.m. For copper, brass, aluminium, Britannia metal, zinc, silver, etc., an experimental speed of 800 revolutions per minute is a good basis to start from, and it will be found possible to increase on this speed up to 1,200 or more, depending on the skill of the operator.

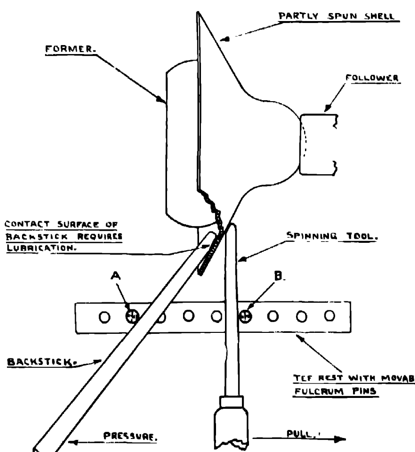


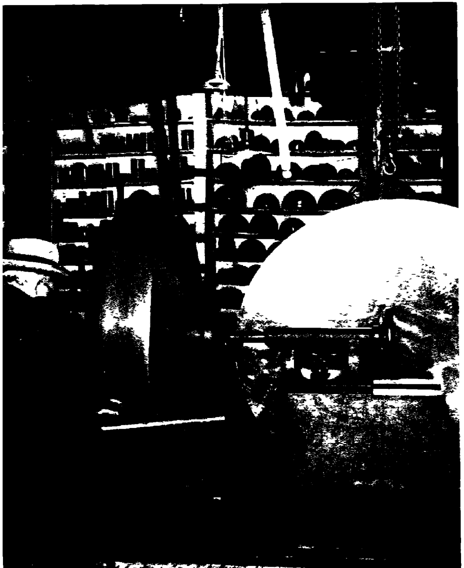
Fig. 99.—Use of back stick.

Lubrication of the Work.—It is necessary that the friction between the head of the spinning tool and the work be reduced to a minimum,

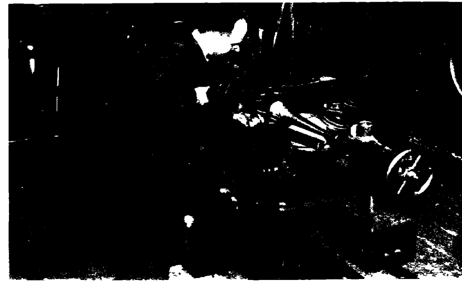
in order to prevent excessive heat being developed, and also to enable the tool to glide freely over the surface of the work without tearing, scratching, or cutting the metal, or the tool itself being damaged. For this purpose lubricants are applied to the metal disk from time to time as required, different lubricants being employed according to the metal being worked. Common soap or animal tallow is frequently applied for steel spinning, while for brass, lead, silver, gold, zinc, and aluminium, tallow wax, usually in the form of a candle, is often used. A soap-and-oil mixture is also quite popular with some spinners, the soap being cut to a size suitable for holding conveniently, dipped in heavy oil, and then smeared across the face of the revolving disk, great care being taken so that no personal unjury results from contact with the edge of the disk. The metal must not be allowed to become dry at any time, and frequent applications of the lubricant are much better than applying a large quantity at the commencement of spinning and hoping that this will see the job through. The lubricant applied to the disk is actually sufficient to lubricate the tools also, but occasionally workers prefer to apply it to the tool direct.

Some metal spinners regard the use of the proper lubricant as the most important item in the whole job, making quite a fetich of the matter, having their own formulæ, which they guard as closely as a valuable trade secret, even varying the proportions of the constituents to suit the climatic conditions so that the mixture will adhere to the disk for a considerable time. One such lubricant is made by shredding 1 lb. of ordinary yellow soap into 3 pints of water, boiling until the soap is dissolved, then adding 1 to 1½ quarts of engine oil (a special variety was actually mentioned), the whole being thoroughly beaten, so that when cool it assumed the consistency of cup grease. The quantity of oil added was greater during the winter months than in summer. A special pad for use with this mixture was made from porous cloth rolled tightly, and tied with string. Mixtures of lard and white lead, or vaseline and graphite, are also recommended.

Annealing.—The process of spinning hardens the metal by reason of the compression and stretching which takes place when shaping to the form, even though lubricants, no matter how efficient they may be, are applied. After a little experience, however, the point at which the metal requires softening or annealing will make itself obvious to the spinner by the difficulty experienced in working. The work has to be removed from the lathe to receive this process, and the metal should have been so far advanced on the former as to provide a location which will ensure that when it is replaced it will assume exactly the same position and revolve as truly as before removal. At this stage of the work the benefit of the sliding tailstock centre will be apparent. Different metals require different processes to soften them, and after softening retain their pliability for a longer period than others. Alloys containing nickel, for instance, require annealing far oftener than other metals, whereas



A



B

C

(H. M. Stiles & Sons Ltd.)

METAL-SPINNING

(A) Final operation on aluminium drum cover, approximately 4 feet diameter. (B) Metal-spinning operation—final planishing brass flare. (C) Close-up view of (B), showing how the tool is controlled by the rest.

provides sufficient heat to render the metal pliable If working on metal formers, these too should be heated.

Constructing the Formers.—For the purpose of describing the actual job of constructing the former for hand spinning, an article shown in Fig. 82 may be taken, say the 4-inch aluminium kettle lid shown at S5. This article presents an interesting feature owing to the fact that the greatest diameter is not at the outer or finishing edge of the component but within the article itself, and shown clearly in Fig. 100 at A, which represents a sectional drawing of the lid after spinning is completed. Having clearly visualised the shape of the work, attention must then be paid to the means whereby it can be produced, and the type of former on which it can be spun. If a solid former be made of the exact size of the interior of the lid, and the metal spun round it as at B, it would be found to be impossible to remove the spinning from the former without destroying the latter, either by hacking it away, or if of wood, burning it out. This would mean that a new former would have to be made for each lid produced, and is, of course, impossible from the point of view of economical production. The alternative is to devise some method whereby the former, after use, can be withdrawn, and this is accomplished in the manner shown at C. The material used will vary according to the number of reproductions of the lid required; if for just a few, wood, of a close and hard grain as maple, will be used; if for a medium quantity, lignum vitæ would prove satisfactory; but if large quantities are contemplated, then the use of metal formers is recommended. There is, however, very little difference in the actual work required to make the formers, whatever material is used. Referring again to Fig. 100 C, it will be seen that several pieces are employed in the construction of this special former or chuck. The drawings 1, 2, 3, and 4 are sections taken on the centre line, the elevation being circular in each case. At 1 is shown the piece which takes the drive from the lathe headstock, the tapped hole being suitably threaded to fit the spindle, the right-hand edge carrying a domed face of the radius to which the lid is to be formed; part 2 has

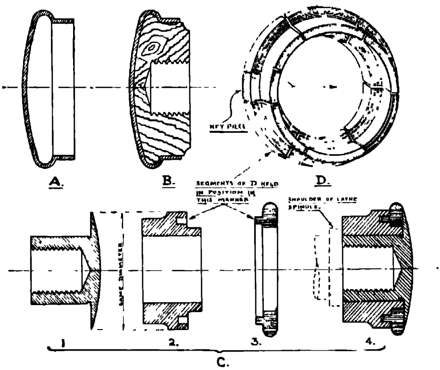


Fig 100 —Constructional details of sectional former

an external diameter equal to the inside diameter of the lid flange; the ring 3 is formed with its outer edge or lip corresponding with the internal groove of the lid, while the manner in which it is fitted in relation to the other parts of the chuck is shown in the assembled drawing at 4. To ensure the removal of this ring when the spinning is completed, it is divided into sections in the manner detailed in Fig. 100, D. In making these divisions, special care is needed, it being essential that one piece, shown shaded in the drawing, should be capable of being removed in the direction of the arrow, that is, towards the centre of the ring. When the spinning has been completed, the work is removed from the chuck by firstly drawing out part 2, then removing the key piece of the ring 3, when the remaining parts of the ring fall out or are easily withdrawn, after which part 1 can be finally withdrawn Should the shoulder of the headstock spindle not be of greater diameter than the boss of part 1, as shown in C4, a washer will be necessary in order that part 2 may be held in position.

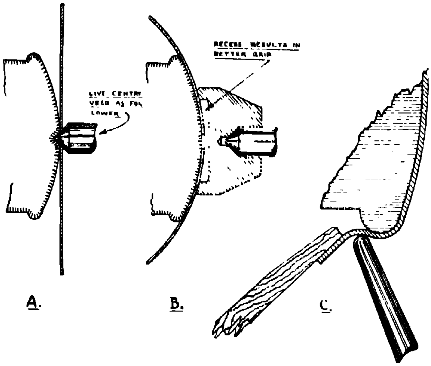


Fig 101.—Spinning with

The chuck or former having been mounted in the lathe, a piece of metal is taken and positioned centrally, the follower being advanced to hold it in position. The size of the disk necessary to produce the article can be roughly determined by following the outline from the centre of the circular elevation to the edge of the component with a length of cord, using the dimension obtained as the radius with which to describe the necessary circle to which the disk is to be cut. As, in the kettle lid under consider-

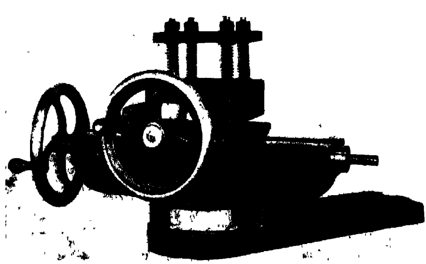


Fig 102 —Compound slide

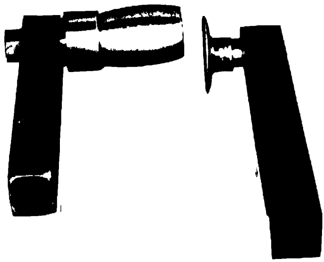


Fig 103 —Roller and wheel tools

ation, the spinning commences right from the centre, and it is permissible to have a small hole in the component for the purpose of attaching a knob later, the live centre itself can be used as the first follower, as at A in Fig. 101. When the domed face has been partly spun, working from the centre as previously described, a recessed follower as at B should be introduced, in order that a better grip of the work be obtained The stage in the work which will have been reached from the first setting of the fulcrum pin (which should have been located slightly to the right of the disk in its flat condition) is also shown at B, the spinning tool being used in a position slightly below the centre. It may be noted here that the spinner soon becomes accustomed to the most satisfactory position of the fulcrum pin just as he does to his bodily position in relation to the work, and his personal comfort. For the formation of the rim of the lid, which should not be attempted until the dome face has been snugly fitted to the former, the use of the back stick, as shown at C, is advisable in order to steady the unsupported edge whilst rounding the curve The flat portion is then spun down to the former. Trimming the edge may be performed whilst the work is still in the lathe, or mechanically in the manner outlined in the succeeding pages, the question of the quantity produced being the determining factor. If there were more than 100 to be trimmed, economy would result by trimming in a machine specially designed for the purpose, or by adding to the spinning lathe the trimming appliance described later. The job is then planished to remove tool-marks, scratches, etc., the final finish of hand-spun work being greatly enhanced

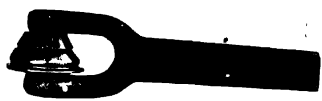


Fig 104 —Seam-closing tool

Fig 105.—Planishing wheel tool.

if the job is first softened by annealing.

Mechanically Actuated Tools. — Certain types of work in metal spinning can be performed by mechanical means, the lathes on which the work is performed being fitted with a compound slide rest, not unlike that of an ordinary lathe, as will be seen by the illustration (Fig. 102). Tools for various purposes can be used in conjunction with this rest, and a selection is shown in Figs. 103 to 108 The use of the roller and wheel tools of Fig. 103 will be obvious to the reader later in the chapter when a typical job in which they are applied is described. With the wheel tool (Fig. 104) seams joining the bodies and bottoms of a built-up vessel can be formed, the application of the wheel gradually shaping the seam by means of the grooves shown. The planishing wheel tool shown in Fig. 105 is of sturdy construction, with large bearing surfaces, adjustment, and oiling arrangement. These features are necessary in order to ensure that the wheel shall run truly and without vibration, and so by constant and unvarying contact with the work impart to it the planished finish. It will be noticed that in Fig. 106 the wheel revolves in a plane at right angles to that of the other tools shown, this tool, with a suitable forming wheel, being useful for work inside the shell being spun. It can be used in the additional slide (Fig. 109), whilst another wheel held by the toolholder of the main rest

Fig 106 — Internal wheel tool

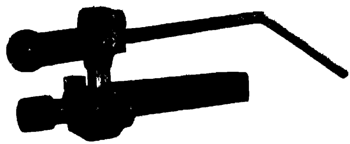


Fig 107 — Seaming and beading applianc

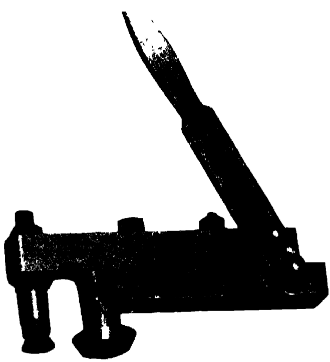


Fig. 108 — Trimming appliance for use in slide.

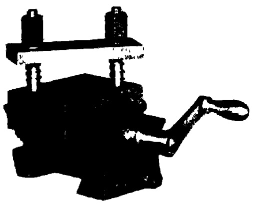


Fig 109 —Additional slide

(Fig. 102) is operated against it on the outside of the work. The appliance (Fig. 107) is also of special interest. With this tool, which can be used on either round or oval work, a turned-over edge is added to the spun work. The rollers are situated above each other and have the advantage that when moving the slide into position only a short movement is necessary, whereas the closing of the edge is done by the lever movement shown. Various adjustments are provided, as will be seen from the illustration. The trimming tool (Fig. 108) operates in exactly the same manner as previously described, but is carried in one of the slide tool-holders. The rollers of the wheel tools shown are interchangeable, and a large variety of shapes are available, as will be seen by the illustration (Fig. 110). In order that two tools may be made to operate on the work at the same time, an additional slide, as shown in Fig. 109, can be attached to the bed of the rest (Fig. 102). Independent control of the two tools is therefore obtained. It can therefore be assumed that in this manner a large variety of work can be done, and assuming that the internal diameter of the shell is large enough to permit the entrance of the follower from the tailstock (which can be of special design) and leave room for the working of the internal roller.

A typical set-up is shown in Fig. 111, the article to be spun being similar in form to the body of a domestic pan. There are several points to be considered, even in a job so apparently simple as this, and planning is necessary before a start on the job itself is made. For instance, the internal roller A must be made of such diameter that the shank of the tool will not foul the mouth of the vessel when the spinning has reached its completion, since the distance from the tool shank to the outer edge of the roller must be equal to C plus a small margin of clearance. Alternatively, this same job could be carried out by using an internal roller shaped to the contour of the article in its finished state, as shown in Fig. 112. The spinning is done by the application of a narrower roller of suitable face applied externally, the various movements of this tool being controlled by the operator manipulating the slides of the compound rest. As with hand spinning, the shaping of the work has to be done gradually, and the fact that additional power is obtained by the screws of the slide rest does not mean that the operator has merely to apply pressure without attention to the behaviour of the metal being worked in order to produce satisfactory results. Thought must also be given as to the best point at which to commence operations. In the set-up of Fig. 111, the obvious commencing point will be at the bottom of the shell,

from which point the roller is alternately drawn along the whole surface being worked, and back again with one slide. With the other, pressure is applied, increasing as it nears the centre of the job, then decreasing. This process is repeated until the metal truly conforms to the shape of the forming roller. In these descriptions it is assumed that the shell has been pressed and comes to the spinner parallel sided, with or without the bead shown in the drawings, and that it has been made of such a size that allowance has been made for the shrinkage in the dimension D. If trimming and beading was not previously performed, tools shown in Figs. 107 and 108 will quickly accomplish this and so complete the work. When working jobs of smaller diameter, using the same method, more room in the interior of the shell can be provided by the use of a follower of special design to hold the work in place. The idea is illustrated in Fig. 113, and it will be seen that while the centre lines of the tailstock spindle and the work are the same,

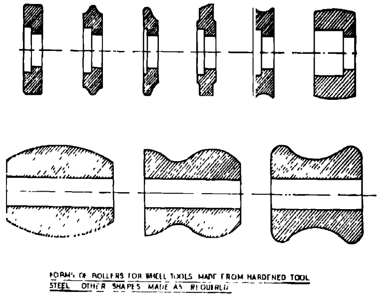


Fig. 110.—Sectional views of spinning rollers and wheels.

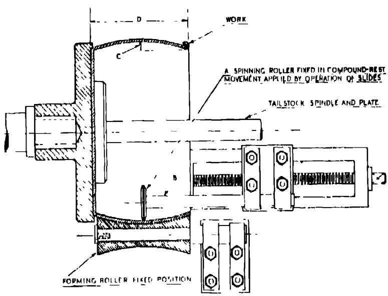


Fig. 111.—Mechanical spinning to external roller.

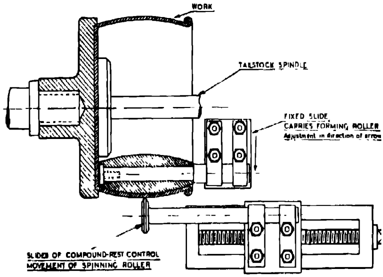


Fig. 112.—Mechanical spinning to internal roller.

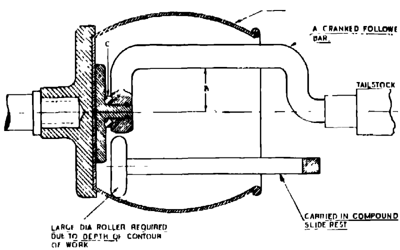


Fig. 113 Cranked follower

the connecting bar between the tailstock and the follower A is cranked, as shown, to the greatest extent which the particular job will allow. In this way an additional operating space, equal to the distance B, is obtained. The crank is solidly fixed at the tailstock end, so that it does not rotate at that point, but remains in its set position to give the maximum clearance to the operating tools. A live centre is necessary, however, and it is arranged at the forward end of the crank in position C. Where spinning is carried on extensively, it is customary to have as part of the equipment several of these cranked followers of different sizes.

Unit-roller Design.—Where the quantity of the particular component being made is large enough, the rollers used internally on the shell and the live centre can be designed as a unit, an example of this being given in Fig. 114. The work is shown securely pressed against the headstock face-plate by the follower B, which gives the necessary friction drive, the follower B being free to revolve on its bearing-pin C, provision to take the thrust being made. At E is shown the forming roller, specially designed for the job, this roller running on the bar D, which is attached to the tailstock spindle in the manner shown. The amount of offset which bar D will have in relation to the tailstock spindle will depend upon the diameter of the work, and will be determined by the position of the contour of roller E. The distance between the centre of rotation and the edge of the roller should equal the radius of the component at that point, less the thickness of the metal. The connecting link between bar D and the follower pin C will have the same centre distance as F at the tailstock end of bar

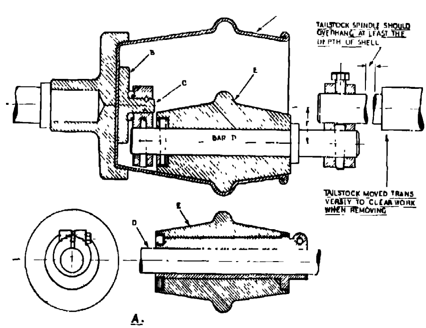


Fig 114—Set-up embracing follower and roller.

D. Where it is desirable that small adjustments should be made in the position of the forming roller, as, for instance, if several sizes of the same article have to be made, varying in diameter but having the same form in the other direction, this can be accomplished by the arrangement shown in Fig. 114, A, the general set-up of the job being similar to that just described. Between the shaft D and the roller E, however, an eccentric bush is introduced, and the roller runs freely on the outer diameter of the bush, which can be rotated and locked at will on the shaft D. It will be seen from the drawing that roller E can be advanced or retarded an amount equal to the throw of the eccentric, or locked at any intermediate point. An alternative method, though not recommended, is to have the links between C, D, and E to tailstock adjustable, but it should be noted that any variation or inaccuracy of setting the two links in relation to each other would reflect on the shape of the finished component. Spinning to this form of internal roller support is done with an outer roller operated from the compound rest, as previously described.

In mechanical spinning each job brings along its own particular problems, and design of the fixtures necessary to produce a component varies accordingly. Great care has to be taken to ensure that after a spinning is completed the forming rollers can be withdrawn through the neck of the spinning, even if this has been reduced to very small dimensions. In some cases, owing to great reduction of diameter in various parts, the spinning may require the use of several forming rollers, each one carrying the work gradually from one stage to the next. It may, for instance, be possible to use a large-diameter roller to rough out the body of the job, leaving the formation of a narrower neck to a second roller. Such a job is illustrated in Fig. 115. The first stage, shown at A, would be performed with roller D, the shell being reduced to size by alternate application of the external wheel tool at the points E and F. The second reduction is performed with roller B, whose diameter at G must be less than the dimension H. The operations which have been performed by the first roller will have formed a locating surface, which will hold the work steady for the present job. The metal of the shell is again worked gradually from either side until it finally assumes the shape of the former.

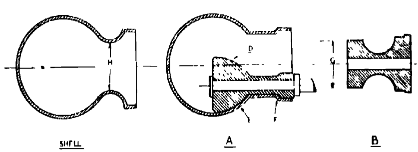


Fig 115.—Two forming rollers for narrow-necked shell.

Countless jobs could be described, each possessing some peculiar feature, or requiring specially designed equipment for the production. No useful purpose, however, would be served, by such descriptions, as more likely than not the first job the reader was called upon to attempt would be of a type not mentioned.

Special Machines.—Special machines are available for the finishing of spun work, such as the trimming of the edges, which are usually rough on the completion of a job, and of too large a diameter. After the trimming, it may be desirable to roll the edge over to form a bead, for strength and appearance. The machine shown in Fig. 91 carries equipment for performing both the above operations, and is made in various sizes from 7 to 18½ inches from bed to spindle centre, while the overall length of the bed ranges from 4 feet on the smaller sizes to 7 feet on the 18½-inch lathe. The tailstock, as will be noticed in the illustration, is of different design from the type described when dealing with spinning lathes. The reason for this difference arises from the fact that the machine is used for the trimming and beading of components which have already been spun to shape. The live centre is, therefore, replaced by the flat plate, which will be seen at the end of the spindle, this plate being free to revolve, a ball thrust washer having been fitted. The tailstock spindle, like that of the spinning lathe, also has means of quick withdrawal, as the components which will be handled will come for trimming and beading in quantities; an accurate setting is therefore made to the first of them, and the adjustment for the remainder is purely mechanical. A chuck, suitable to the component (as will be described later) is fitted to the headstock, the component inserted, and the tailstock spindle pushed up to it. The handle seen projecting is locked to the spindle at the forward end, and on being brought forward and down engages in the slot which can be seen, and which has a cam face, thus adding that little extra pressure necessary to hold the work securely. Inserting or removing the work is simply a matter of engaging or disengaging the lever from the slot, and sliding the spindle in the direction desired.

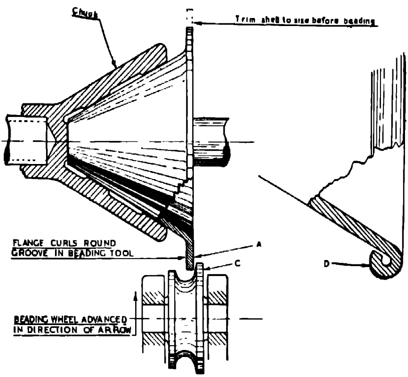


Fig. 116.—Operation of beading

The action of the trimming cutters was fully described in connection with Fig. 92, and in the machine shown a beading wheel works in conjunction with the trimming wheels, both appliances being mounted on the same slide. The trimming operation is performed first, then the bead is formed on the component. Adjustment is provided to deal with

work of different diameters, and the tools can be turned in their holders, enabling operations to be performed on work either at right angles to the centre line of the lathe bed, or at some other angle, say 45°, according to how the flange from which the bead is to be formed was left in the production of the shell. The method in which the bead is formed is illustrated in Fig. 116. It will be seen at A that a flange has been left on the component which, when it is in position in the lathe, projects at right angles to the lathe bed. The position of the slide of Fig. 91 is correct for forming the bead from this flange, the wheel C being advanced so that the metal shapes itself to the groove forming the completed bead shown in section at D. When the flanges are formed at the angle of 45°, as is very often done, the action for both trimming and for the formation of the bead is the same, but the tools are led to the work also at the angle of 45°.

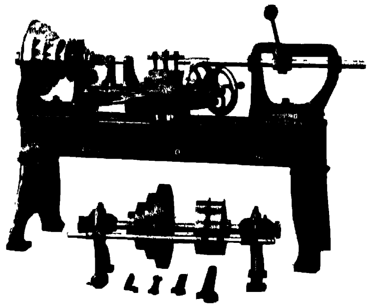


Fig 117 — Planishing or burnishing lathe

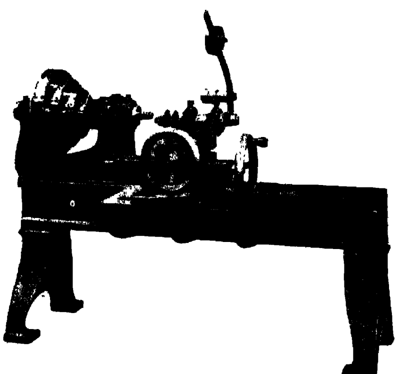


Fig 118 — Spinning lathe with polishing attachment

The edges of spun articles are greatly strengthened by enclosing a stout piece of wire within the bead. As in the hand process, the wire of correct length to encircle the article is tacked in position with the special pliers, the bead being closed round it with the beading tool, a suitable wheel being fitted to allow for the

increased size of the wired bead. Stops are provided on the slide, which is operated by the handle seen at the front, and when the stops have been set to the particular job, the remaining components can be machined without further adjustment, the finished diameters of both trimming and beading being always the same.

Finishing Processes.—The finishing process for a spun shell is known by the term burnishing or planishing. In the hand process a wide-faced spinning tool is applied, but mechanically this is done by means of rollers, a variety of shapes being available. One of these is passed over the surface of the work, a higher speed being applied for this process. The roller tools shown in Figs. 103 to 106 can be used, manipulation of them being done through the slides of the compound rest.

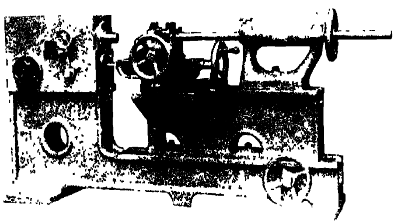


Fig 119 —Motorised headstock applied to spinning lathe

A lathe specially built for the process of planishing or burnishing is shown in Fig. 117. The bracket seen attached to the headstock is adjustable in a direction across the bed of the lathe, the correct setting depending upon the diameter of the work being operated upon. The two vertical brackets carry a spindle on which a forming roller is mounted. They, too, can be set closer or farther apart from each other to suit the width of the particular forming roller in use. A typical example of a job which could be done on this machine with advantage is the component shown in Fig. 111. The bellying process would be performed by fitting a suitable concave roller between the brackets, bringing the metal to shape with an internal spinning wheel. The planishing would be done with the same setting, speeding the work up for the final operation. The bead may be turned either before or

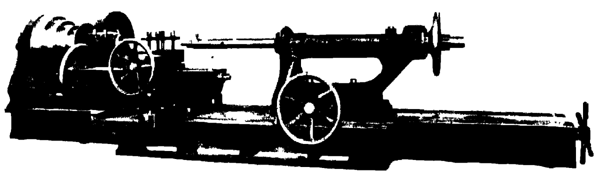


Fig 120 —Spinning and planishing lathe for heavy work.

after this operation. The compound rest of the lathe, not having to carry the former, is left entirely free for other operations.

The machine illustrated in Fig. 118 carries a polishing attachment on the top slide of the compound rest. The movement of the attachment is governed at the will of the operator by the compound slides. The spindle is driven independently of the lathe headstock, the driving belt being kept tight in all positions by the jockey pulley and weight shown. With this machine, a job can be carried right through the stages of spinning, planishing, and polishing, with one setting-up of the work. The polishing head can, of course, be replaced by trimming or beading tools when necessary. The useful flanges on the spindle of the polishing head will hold securely spinning wheels of various types, or can be replaced by polishing buffs where a particularly fine finish is required. The greatest advantage of this attachment will be appreciated when

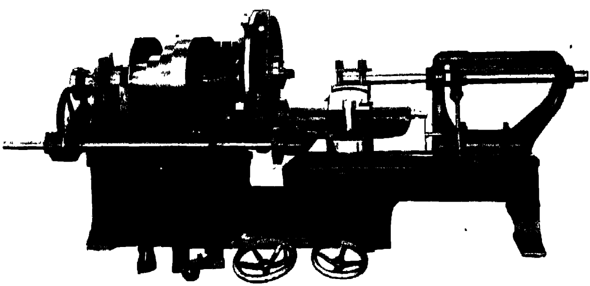


Fig. 121.—Lathe with chuck for oval work, and with screw-cutting attachment

work of a difficult design is being performed. Once the job is set in the machine, the whole of the operations are completed before removal.

The operation of planishing proper, besides smoothing and improving the appearance of the spun work, results in a closing and hardening of the grain of the metal being worked, due to the pressure applied uniformly over the entire surface. An article after being treated by this process is more rigid and retains its shape better.

Electric driving power is applied to the lathe illustrated in Fig. 119, the headstock spindle being driven by an electric motor built solidly in to the headstock itself. Six different speeds are obtained by the use of a gear box and the two speeds of the motor itself, the controls being clearly seen. The cranked handle operates the gears, the lower handwheel starts the motor, while the top handwheel locks the spindle to facilitate operations when setting-up, removing chucks, etc.

A contrast to the machines described above is shown in Fig. 120, the principal dimensions of which are: length of bed about 20 feet, height to centre about 2 feet, distance between centres 10 feet. The tailstock has the usual quick-withdrawal feature, and in addition a screw, operated by a handwheel, for making the finer adjustments. A movement across the lathe bed is also incorporated, the purpose of which is to enable a forming roller to be moved for the entire depth of its curved portion, and withdrawn from the shell without disturbing the same.

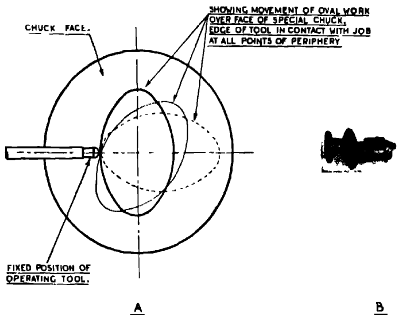


Fig. 122.—Showing oval work, and special tailstock follower attachment.

Oval Spinning.—Work which is oval in shape, such as the domestic dishes of that shape which will be familiar to the reader, can be spun on the interesting machine shown in Fig. 121. The main feature of the machine is the special chuck, which is so designed that when in operation it slides the work in a direction over the diameter of the chuck itself, the amount of movement depending upon the difference between the major and minor axis of the oval. This motion keeps the oval in close contact with the operating tool being used at all times during a complete revolution of the chuck, the action being illustrated in Fig. 122. As the work slides during the process of the spinning, a special type of follower is also necessary capable of a corresponding movement, the design in which these are made being shown in Fig. 122 B. The pallet plate is free to revolve on its bearing pin, which in turn is fixed to the vee-slide shown, and the bearer slide can revolve around the boss shown, which is clamped

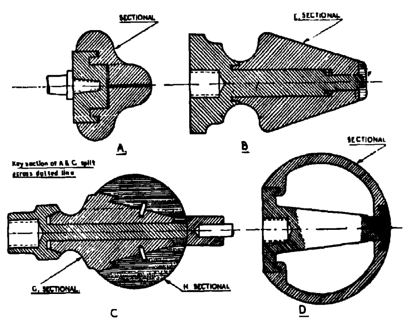


Fig. 123.—Sectional formers.

to the tailstock spindle. In this way the whole of the movements necessary for oval spinning are catered for. A screw-forming mechanism is also fitted to this lathe, which can be used either for forming spun threads on metal containers, say, a large drum, with a spun lid to screw on, or similar work ; or the threads in the various chucks or formers can be cut on the machine itself.

Owing to the size of work which can be performed by this machine, and the one previously described, back gearing is provided. The speed at which spinning can be done is more a matter of surface speed than of revolutions per minute, and the back gear is necessary in the case of large work on a heavy gauge of metal to give a speed suitable to the job. The illustrations for these machines have been supplied by the courtesy of the Benrath Machine Tool Co., Ltd., Manchester, and numerous other types of machines are made, each being specially designed round a particular component.

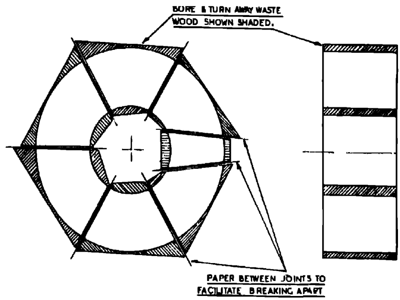


Fig. 124.—Details of segmented ring.

Chucks and other Appliances.—In the preceding drawings and descriptions, various shapes of articles have been considered, and it will have been noticed that in all of them the former has been of the exact shape of the spinning to be made, although in size it is the thickness of the metal less in all dimensions, or in other words, an exact counterpart of the inside of the shell. Mention has also been made of the various materials from which these formers should be made. The shapes shown in Figs. 84, 88, and 97 are perfectly simple, and the drawings are self-explanatory. Full details were given regarding the construction of the sectional chuck required to produce the lid shown in Fig. 100, and a reference to the

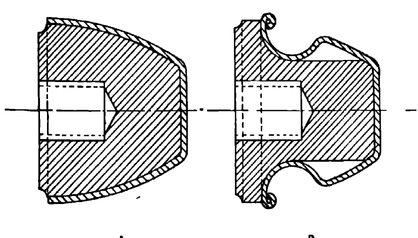


Fig. 125.—Formers for "spinning on air."

shape of the component in Fig. 99 will show that as the mouth of the shell is smaller than the largest diameter of the spinning, a sectional former is again indicated. In this instance, however, the bulge on the component is located at the opposite end of the shell to that of the lid, and a different construction of the sectional former is therefore necessary. This is illustrated at A in Fig. 123. At B, C, and D sectional formers for other shapes are shown. The parts of B slip over each other, the two keys which can be seen lock the parts of the segmented ring E together, while the pressure of the follower on the face F prevents the former coming apart lengthwise during the spinning. Two segmented rings are necessary for the production of the component at C, these being indicated by G and H. The outer segmented ring is held by the loose dowels shown, and owing to the small diameter of the centre section it is turned from steel. For larger spinnings, the former may be constructed in a hollow form, as at D. The main points to watch with sectional chucks is that each part must be capable of being withdrawn after spinning through the mouth of the component, and that a key piece is provided so that the former can be taken apart within the shell. The sectional rings are formed by planing the wood from which they are to be made to the angles of the segments in a radial direction, allowing sufficient material, as shown in Fig. 124, for the ring to be bored to size, and turned to the outer shape. The segments are glued together in their respective positions, inserting a sheet of paper between each pair of faces. When the glue has thoroughly hardened, the ring thus formed is machined to size, then broken into sections again. The paper which was placed between the glued face renders this a simple operation.

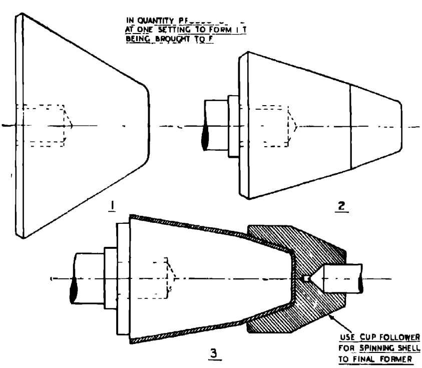


Fig 126.—Formers used for production of deep shell.

For the more simple shapes, where absolute accuracy is not essential, a skilled spinner may adopt a process known as "spinning on air." By this is meant that the work is partly formed by shaping the metal of the job without having a solid former within the part being spun. In this manner, as is illustrated in Fig. 125, a job which in the ordinary way would require a sectional chuck can be performed without the expense

and trouble of making one. Two formers, A and B, are used, the metal being spun over A and then transferred to B, where it is carefully tooled to the finished shape. Greater ease in performing this second operation results if the part to be worked is annealed, leaving the remainder of the shell hard.

In the spinning of a long, deep shell, as, for instance, that illustrated in the centre of Fig. 93, it is advisable that the metal be brought to shape gradually, intermediate formers being used to ensure this. Three may be necessary to produce the shell mentioned, and Fig. 126 shows the suggested stages of the spinning.

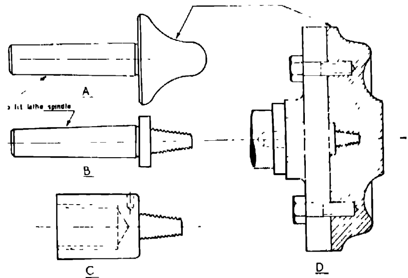


Fig. 127.—Methods of mounting formers

The life of wooden formers can frequently be prolonged by covering them with metal. This is, in effect, spinning a sheet of metal, preferably steel, over the surface in such a way that it will remain in position. Instead of trimming, the edge of the disk is turned over the end of the former, completely covering it.

The method by which the formers so far described have been attached to the headstock spindle has been by threading them directly on to the spindle nose. This is, however, only possible with formers large enough in diameter to allow the necessary threaded hole to be bored and leave a wall sufficiently strong to stand the strain placed on it during the operations. Various alternative methods of mounting formers are shown in Fig. 127, A and B being shown with Morse taper shanks, although where the spindle nose is threaded the taper will be replaced with a suitable thread. At A, where a very small spinning is to be made, the form is turned solid with the headstock fitting, while B shows the driver having a taper thread, which screws into the former. The work runs truer on this form of thread, and there is less tendency for it to strip itself; C carries a

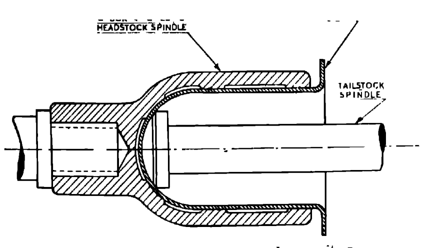


Fig. 128.—Chuck Showing work in position

similar thread, but fits externally on the spindle nose, and at D a large former is seen mounted to a face-plate to give solidity and also to save making a former of much heavier construction.

Formers are frequently referred to as chucks, but actually a difference exists between the two. The chuck is usually the appliance in which the spun shell is held for subsequent operations such as trimming or beading, and in Fig. 128 a chuck is illustrated. Here it will be seen that the grip is on the outer side of the shell, and that it is not necessary that the entire surface be gripped. Locating points are all that is needed to ensure that the shell will revolve truly in the lathe, and that sufficient grip is obtained. The follower in most instances need not be shaped at all, the pallet piece mentioned in connection with Fig. 91 providing enough grip to drive the work in the trimming or beading process. Spinning chucks, like formers, have to be made to suit the job they are intended for and can, in the same way, be made either from hardwood or metal according to the number of components to be produced.

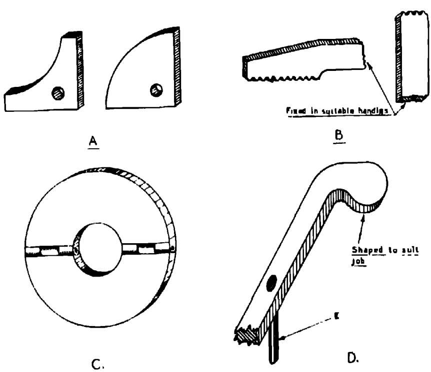


Fig 129 – Useful accessories to metal spinning.

Followers for the spinning process have been described and illustrated in the previous pages, and need no further description beyond mentioning that they should be so designed as to afford the maximum grip. They may be made of either wood or metal.

Where the formers, chucks, and followers are made in the spinning shop, the work can be simplified by the use of the templates, both for internal and external radii, in the form shown at A, Fig. 129. Several sizes of each type should be included so that a range in accordance with the general run of work in the particular shop is available. A few French curves can be added with advantage, to cover those shapes which are a combination of curves of different radii blending into each other. The thread chasers shown at B match the threads on the spindle nose, and are used for the purpose of matching these threads on the chuck or former. Inside and outside chasers are used, and one is necessary for each different type of thread.

Although spinning tools of steel can be used on most jobs, with some metals greater ease of working is obtained by the use of bronze tools.

monel metal, in particular, responding to bronze tools in preference to steel. For copper and pewter a hardwood stick, made, for example, of hickory, is best for breaking down the work, metal tools being applied when it is roughly to the shape of the former. If much work in these metals is contemplated, at least one or two tools of these materials should be included in the equipment.

Where a large-diameter shell has so small a mouth as to render it impossible to insert a follower large enough in diameter to give sufficient grip, the hinged pallet plate shown at C can be used. In action it is folded over, inserted through the mouth, reopened inside the component, the pressure from the tailstock pallet pressing and retaining it in its flat position, location being by means of a spigot on the tailstock pallet, fitting the centre hole.

Knurling.—Decoration can be added to spinnings by the application to the surfaces of a knurling wheel. The wheels are carried in the wheel tool, and a variety of patterns are available, the application being similar to knurling in ordinary engineering practice. The wheel is pressed into the work while the latter is stationary, then the work is slowly turned by hand, pressing the pattern into the metal, and, as it were, gearing the wheel and the work together. After starting in this manner, the power may be applied and the knurling continued to the depth required. The pattern may consist of a single ring the width of the wheel, or may be extended as far as desired along the shell by a repetition of the process.

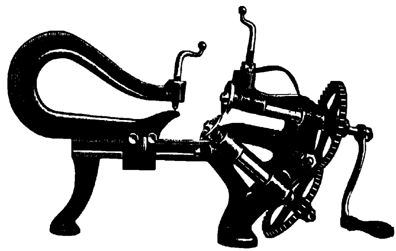


Fig 130 —Disk-cutting machine

For an occasional or isolated job, which does not justify the time and expense of a turned follower, a skilled spinner may use the method shown at D. Here the tool carrying the shape is shown to be of a similar nature to the back stick. It is used in the same manner, but an additional pin E determines its position in relation to the work. This stick is held firmly either by the operator, or an assistant, and the metal spun over the shaped end.

The cutting of the circular disks of metal from which the spinnings are to be formed can be done with a machine similar to Fig. 130, the two cutting wheels being geared together, and the work rotating between them from the centre. Different diameters are obtained by sliding the head carrying this centre to or from the cutters. Plates can be fitted over the centre shown, which hold the work by pressure, and leave it unblemished by any centre mark, as may be necessary with a

particular job. Such a machine should form part of the metal-spinner's plant. The maker of the machine shown is Messrs. G. Kendrick, Ltd., Birmingham.

"Safety First" in Spinning.—In conclusion there is an element of danger in metal spinning, and the following "Safety First" Rules should be observed: Keep the hands or other parts of the body away from the edge of the revolving disk. Although it has no teeth, its danger can be compared with that of a circular saw owing to its very high speed. Always have the machine stationary before inserting or removing the work. Before starting the lathe, make sure that the friction grip on the metal disk is tight enough to prevent the disk flying out when the power is applied; in any case, stand clear of the disk, just as an added safeguard. Keep oil or grease from the follower, for the same reason. If the machine is in the centre of a shop, provide a wire-mesh guard behind the work for the safety of others. When trimming the edges of a disk with a cutting tool, keep clear of the flying chips of metal which may cause injury. When applying lubricant to a disk, or working on same in any way, be careful that the tool does not slip off the edge, as the pressure applied in working may carry some part of the body against the disk with injurious results. If these precautions are taken, danger will be reduced to a minimum.

CHAPTER 7

MACHINES FOR MISCELLANEOUS OPERATIONS

THERE are a number of what may be termed minor operations in the sheet-metal industry which can be performed by machines of a simple character often operated by hand, although if the production requirements demand it, they may be of the more complex automatic type. Some of these machines perform only one process on the metal, while others will do combined operations, which avoid the necessity for separate handlings of the piece between each process. When automatic machines are run in connection with presses, the capabilities of the former must of necessity be equal to those of the latter, so that there is thus continuous production according to schedule. Many of these minor operations are performed by rotary action in the machine. Some of these machines may now be briefly examined.

Indenting Machine.—Indenting or scoring is the name applied to the treatment given to the tear-off strips of tins, such as those for corned beef, enabling them to be easily opened. Straight or curved scoring can be produced, the body blanks being passed over a table having a guide strip which controls the movement, and the machine is so designed that the disks can be readily changed as required. Indenting of another class is performed on the ends of certain articles, for example, cartridge cases, in order to make a recess on the surface of the metal, this being done by means of a die.

Screwing Machines.—The rolling process, which is sometimes employed in the production of threads to be formed on certain classes of solid screws and bolts, is the method practised for indenting the screw thread on sheet-metal articles such as caps, lids, sockets, necks, nozzles, burners, etc. In the simple hand-driven machines, the chuck or screwed former is turned by means of a hand wheel on the spindle, and the threading spindle is fed up by a lever. This type of machine will deal with diameters from $\frac{3}{8}$ inch to $1\frac{1}{4}$ inches, and is secured on the bench. Another bench style, working up to 4 inches diameter, has a belt-driven spindle, with a treadle motion for the feed. More rapid action and more uniform pressures are obtained in the automatic machines, which will screw about fifty pieces per minute, from $\frac{1}{2}$ inch to 5 inches diameter, and 3 inches in length. A larger model, which possesses automatic movements, is shown in Fig. 131, and functions in the following manner. The article is placed on the screw chuck, and the treadle depressed, with the result that the

adjustable clamping tailstock comes up, and the clutch is engaged, the degree of pressure being automatically controlled, thus ensuring uniform threads of correct form. The ratios are obtained from change-speed gears, and a chart is provided to show the correct combinations for different-sized objects. The specification is:

Range of sizes	$\frac{7}{8}$ inch to 5 inches
Maximum length of work accommodated	18 inches
Average production per hour	1,000
Number of ratios of change-speed gears for the complete range	6
Power required	3 to 5 h p

Larger sizes of machines are those which screw the necks and caps of steel drums, admitting drum heads up to 18 inches diameter, and screwing

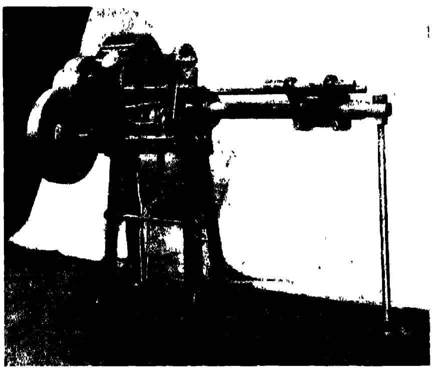


Fig. 131.—Semi-automatic thread-rolling machine. (Hordern, Mason & Edwards, Ltd)

caps up to 8 inches diameter, the machines being hand controlled. The Taylor & Challen machine for rolling the threads on to the lids of drums, which is shown in Fig. 132, has an output of twenty per minute, the minimum diameter being 8½ inches and the maximum 10½ inches. After the lid has been placed on the revolving die, depressing the pedal seen on the right causes the floating die to slide across until it is in line with the screw threads, then the pedal on the left is depressed, which brings the clutch into operation. The back shaft then rotates, and a cam throws over the floating die and keeps the pressure applied until the threads are rolled

Combination Machines.—An interesting class of combination machine is that dealing with two or more processes in which thread rolling is included, the combinations comprising: beading and thread rolling;

knurling and thread rolling; knurling, thread rolling, and curling. Combination machines which do not include threading are: beading and trimming; curling and knurling; beading, recessing, and curling; beading and curling; curling, knurling, and indenting. Both automatic and hand-fed machines are constructed for these services, outputs as high as 6,000 pieces per hour being obtainable on some of the former types. The articles are placed in a chute, from which they roll down to the tools, these being easily changed for the different sizes and shapes. To obtain extremely accurate threads a screwing-off device is fitted, which ensures that the threads shall be exactly to gauge. Fig. 133 is of a triple-operation type.

Rolling Threads on Screws.—Many of the small screws used to fasten sheet-metal articles together are also rolled, this being a quicker and cheaper method than screwing by dies. As the act of rolling makes a screw that is larger in diameter than the wire from which it is produced, this effect has to be countered by the correct selection of the blank diameter. When the thread is rolled, since the surface metal cannot be compressed into the central portions, it has to be forced up to form the vee of the thread, so that when the shank has to be of the same diameter as the threads, the blank must be shouldered and reduced along the length to be threaded. Flat dies are employed, having a series of parallel thread sections set at a definite angle, these being arranged above and below the blank, and accurately set. The movement of the wire is controlled so that the grooves produced by one die will exactly meet those produced by the other when the wire has made a half revolution. The dies are cut with a hob having a face wide enough to cut the entire surface of the die at one setting, the threads having no lead, as have those of ordinary threading hobs, but the thread sections are parallel with the ends.

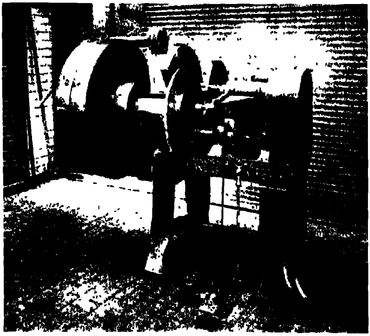


Fig. 132.—Thread-rolling machine for drum lids

The method of procedure for finding the diameter of wire and angle of threads on the dies is as follows: Assuming that it is desired to make dies for a standard $\frac{1}{4}$-inch screw with twenty threads to the inch, right-hand, it is necessary to ascertain the diameter of blank requisite to make such a screw, and from this determine the angle of grooves in the dies. To find the size of wire, first measure the pitch of the screw; this would be $\frac{1}{20}$ or ·05 of an inch, and having determined this, subtract from the

diameter of the finished screw the product of the pitch, multiplied by one of the following factors, which will vary according to the diameter of the screw :

If the screw is smaller than $\frac{1}{8}$ inch	·55
From $\frac{1}{8}$ to $\frac{3}{16}$ inch	·60
From $\frac{3}{16}$ to $\frac{1}{4}$ inch	·65
From $\frac{1}{4}$ inch and over	·70

Therefore, for the $\frac{1}{4}$-inch diameter screw under consideration, the pitch ·05 multiplied by ·070 equals ·035, and the diameter of the screw, ·25 less ·035 equals ·215, which is the exact diameter of the wire required.

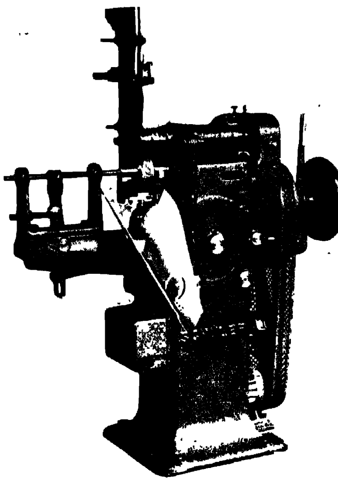


Fig 133 —Automatic threading, trimming, and beading machine (A C Wickman, Ltd)

To find the angle of the grooves on the dies, find the circumference of the wire to be used, and note how many times it is contained in 1 foot, thus, diameter multiplied by 3·14 equals ·675, this being the circumference, and 12 inches divided by ·675 equals 17·77 ; in other words, the wire would have to be revolved about $17\frac{3}{4}$ times to equal the length of 1 foot. As at each revolution the incline of thread would be ·05 in $17\frac{3}{4}$ revolutions, the incline would be $17\frac{3}{4}$ multiplied by ·05, or ·88. This would therefore represent the incline per foot at which the dies would have to be set on the milling machine.

Rotary Swaging Machines.—A different system of reducing or tapering from that produced by dies is much employed in the rotary swaging machines. The sheet-metal tube (or the machine can be used for swaging a rod) is passed through a spindle which has hardened rollers running at high speeed, and these hammer the work by a number of

light blows into the form desired. The action is gentle but positively formative, giving a fine, smooth finish, while the metal becomes consolidated and made tougher and stronger.

Closing Machines.—The operation of pressing the lids or the ends such as are used in the production of certain kinds of receptacles often calls for the use of machines that facilitate this work, as, for example, if the lids are secured after the receptacle has been filled. For small tins and canisters there are both hand-manipulated and automatic machines designed to do this job. The former type consists of a round pillar on a bench stand ; at the lower part of the pillar a table is clamped at a suitable height, and above this is a bracket through which slides a spindle actuated by a lever. After the tin is filled with paint, treacle, etc., it is placed on the machine, and the spindle carries a closing disk which descends on the lid and closes it over. The automatic type of lidding machine deals with about 100 canisters per minute. These arrive at the machine on a travelling conveyor band in single file, while round lids are placed loosely in a hopper, from which they are automatically released and pressed on to the bodies. Lids which are not round must be fed into the delivery chute by hand.

A heavy class of machine has been designed for pressing the tops and bottoms into the bodies of 40-gallon drums previous to the flanging and seaming operation. A horizontal bed supports right- and left-hand headstocks, each holding a chuck on a slidable spindle. The tops and bottoms are put on these chucks, and the body is rolled in on to a cradle between the chucks. When a pedal is depressed, two top and bottom jaws close round the edges of the body, to give it a perfect circular shape, and, while it is thus held, the two chucks move forward and force the tops and bottoms into the body.

Cartridge Machinery.—A number of special machines are utilised in plant designed specially for cartridge manufacture, and a brief review of these may be of interest. The operations involved concern both the production of the cases and the bullets. In the initial stages, certain presses, of types which have already been described, are employed, but several special kinds of machines are required which have no place in other branches of sheet-metal work. The first process performed on the sheet metal in the production of the cases consists in cutting and cupping, this being effected in rather powerful open-fronted or double-sided presses provided with feed rolls, the leading ones having a pad which cleans the strip ; scrap shears are also fitted. Among the differences between these special machines and the more normal types are that the press stands in a suds tray, and that, in many instances, multiple tools are arranged (Fig. 134), both for making cases and bullet envelopes. One of the latter kind of presses operates four tools, and at 300 working strokes per minute the output in that time is 1,200 cups. Each respective set of tools on one machine has its separate feed chute, in order to enable the attendant to examine the individual working of each set of tools.

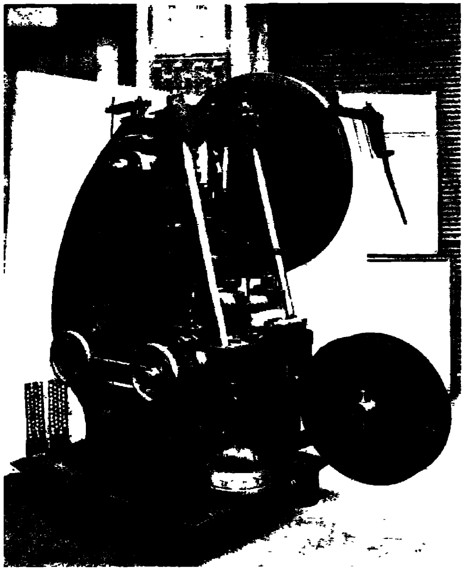


Fig 134 —Cutting and cupping press, using multiple tools

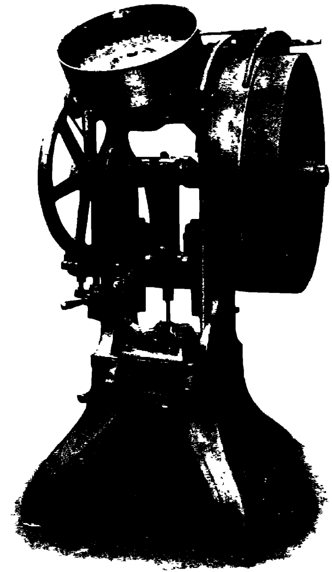


Fig. 135 —Hopper-feed press for first drawing operation on cartridge cases. (Taylor & Challen, Ltd)

Drawing and extending are performed in several stages, with intermediate annealings. On some machines, feeding is by turntable, horizontal presses using chute feed, but the large cases must be hand-placed. The combination of dial and hopper feed occurs in some instances, the units from the hopper automatically coming down into the holes in the dial, the hopper being so designed that it cannot over-feed. A different combination is employed on a machine that passes the cups from the hopper on to a revolving plate, on the periphery of which slots are cut

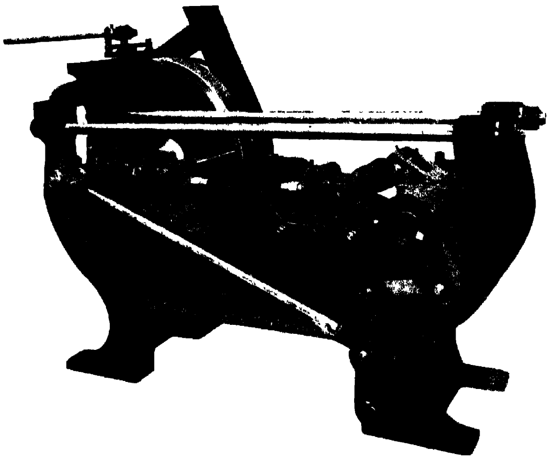


Fig 136 —Cartridge-case indenting press

to the correct form of the cups. The latter, falling into the slots, are taken around and dropped down a chute, whence they are carried to the die by a pusher (Fig. 135).

After the indenting process, which is done in a horizontal press (Fig. 136), the cases are taken to a tapering press (Fig. 137), where they are transferred by an automatic pecker feed to the dies and tapered, the head is then rectified, and the pushed cases are ejected at a speed of about sixty-five per minute. An additional attachment may be included which rectifies the mouth before the dies are reached, dented or elliptical mouths being thus trued to a circle.

The heavy work of heading demands the use of very strong horizontal

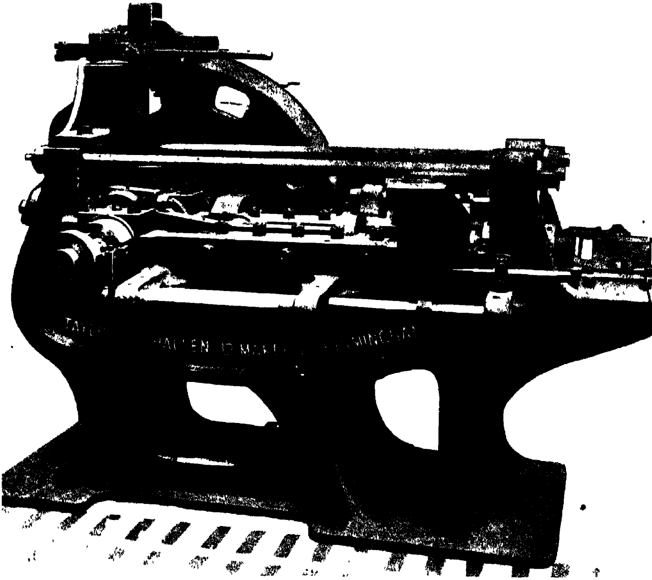


Fig. 137.—Cartridge-case tapering press

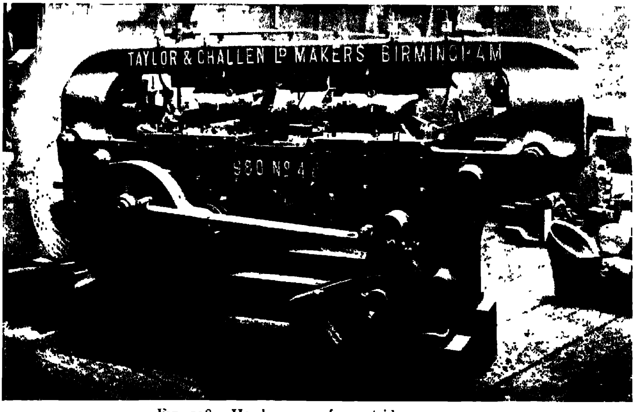


Fig. 138.—Heading press for cartridge cases.

presses of the closed-frame type (Fig. 138), in order to eliminate all risk of springing, the heading slide and the extractor slide being actuated by toggle mechanism from the crankshaft. From fifty to ninety strokes per minute are made in the various machines of this type, and from 3 to 5 h.p. is required for driving the different presses.

After successive drawing operations, which are followed by a trimming process, bullet envelopes are "formed" in three stages in a horizontal type of press, equipped with chute feed. The parallel-drawn envelopes roll down to a slide, where they are taken separately under a pair of fingers, which places them in front of the die, the extractor entering at the back of this die and pushing out the formed envelope, whence it falls into a box, the rate being about seventy envelopes per minute.

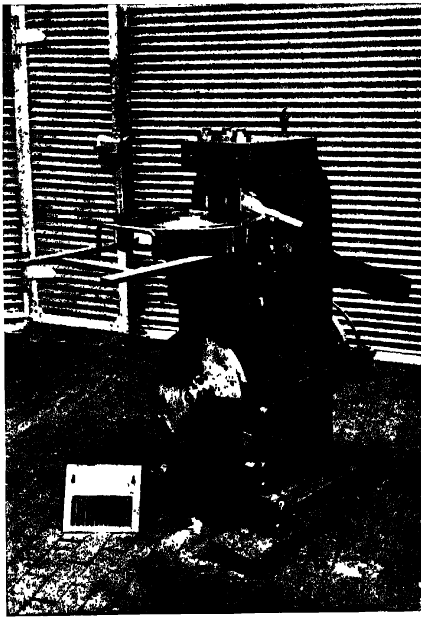


Fig. 139.—Bullet-pressing machine having a turntable and three sets of tools

Bullet-pressing Machine.—A special turntable design of press is used having three sets of tools, the process being as follows: the bullet envelopes, complete with aluminium tips and lead cores, are fed on to a turntable, and this carries them around between the three sets of tools which are fixed in an overhanging head. As the table slide rises the first set of tools forces the aluminium tips and lead cores into the envelopes, the second turns over the envelopes, and the third extracts them, so that they fall away down a chute. The top tools are adjusted by screws and nuts, and there are thirty stations, the number of strokes per minute being 100 (see Fig. 139).

Frazing and Reamering.—Frazing, or trimming to length, and mouth reamering require the service of a horizontal dial-feed machine, which

for the size under consideration works at the rate of 140 cases per minute. The frazing and reaming spindles run at 2,500 revolutions per minute, and a ten-hole dial is employed which moves one-fifth of a turn per cycle of events, so that the operations are done in duplicate. The sequence on these five pairs of centres is : (1) the cases are pushed from two chutes into the dial ; (2) they are frazed and reamed ; (3) cleaned by brushes ; (4) gauged to length ; and (5) ejected.

Turning and Reaming.—An automatic hopper-feed machine is responsible for the head turning, trimming to length, and mouth reaming, the cases being separated from the swarf after ejection, the rate of output being thirty-five per minute.

Firehole Piercing or Drilling.—The fireholes may be either punched or drilled, special machines being available for both processes. In a combined piercing and marking machine of the vertical double-standard pattern, a crankshaft lies at the bottom of the framing and moves a slide lying below a turntable into the holes of which the cases are placed, mouth downward. The dies carried on the slide enter from underneath and lift them slightly against the punches, the marking dies being in a fixed holder in the head of the press.

In two designs of machine where drilling is employed one has chute feed and the other turntable feed, the production rate being about fifty per minute. The drills have a speed of rotation up to 11,000 revolutions per minute.

Marking Machines.—For the purpose of marking the heads only, a hopper-fed machine is built to work automatically, the punch approaching horizontally, while in another design a vertical press is employed which rectifies the cap chambers and letters the heads, double-crank drive being fitted to ensure even pressure, and a turntable transfers the cases underneath the punches. A final handling is necessary for the process of gauging ; the cases fall down a chute at the speed of seventy a minute, wherever they are passed through the gauges, the rejected cases falling in a different direction from the true ones, which go into a box.

Capping Machines.—Both vertical and horizontal types of machines are employed to fix the caps in the cases. The vertical press has a turntable feed, and handles either empty or loaded cases. For the latter, firing tubes are provided under the punch centres as a safeguard against accidental explosion, the capped cases being ejected automatically. A combination of hand-placing of the cases in the feed wheel, and automatic supply of the caps from a hopper, occurs in the horizontal machine. At each revolution a cap is brought opposite a case and in line with the punch, which advances and pushes it into the chamber, the primed case being carried on and extracted.

Tin-foiling Machine.—A small multiple-die press carries a sliding plate containing caps in the numerous holes, and at each stroke nine disks

are cut out and inserted in the caps, the tinfoil being fed so as to leave the minimum quantity of scrap.

Cannelурing Machine.—The function of this machine is to roll the grooves in the bullets. A table is provided with a spindle projecting above it, the latter carrying the revolving disk which impresses the grooves in the metal (Fig. 140). There is a steel segment on the table at one side of the disk, and a thrust block at the other side to prevent the side pressure from affecting the spindle, the bullets being fed down a tube, pushed forward automatically, and rolled between the disk and segment The various other types of machines which are utilised in a cartridge plant hardly come within the scope of a treatise on sheet-metal work.

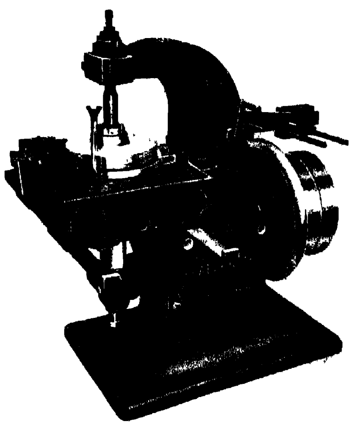


Fig. 140.—Cannelurіng machine which rolls the grooves in bullets.

Marking Machines.—As distinct from the machines described above for cartridge-case heads, hand- and oil-operated marking machines are available for general service, to impress names, figures, trade marks, and lettering on flat or round metal articles. The principle employed in both classes of work is to have a vertically elevated table to carry the work, and an overhead slide which propels the die across. For flat surfaces a round die is used, and for round surfaces a flat die, so as to roll the impressions in. The slide is moved across by a hand lever, and the table raised by a pedal to put on the pressure, an adjustable stop regulating the height of movement. In the hydraulically operated machine the power enables it to mark up to ten lines of $\frac{1}{8}$-inch letters, to a maximum length of 7 inches. The oil pressure is maintained by a small rotary gear pump, and on depressing the pedal the power is used automatically to elevate the table to the required height and to feed the die across, the table then dropping and the dies returning to their original positions. If the pedal is kept down, operation becomes continuous, but the speed of travel of the die and the pressure of the table may be varied by means of valves.

Engraving Machines.—Engraving machines (Figs. 141, 142) are employed to cut figures, letters, designs, etc., on any sort of metal articles by a

milling process, the pantograph principle being usually embodied to give the necessary reproduction from the original copy. The simple cutters are ground on their ends to a suitable shape to produce straight or bevelled sides, or flat-bottomed cuts when these are required to be filled in with paint or other substances. The cutter spindle is driven by a cord which runs over guide pulleys in such a manner that the extreme movements of the cutter head over the work are accommodated. The piece is clamped to a T-slotted table, and the pantograph frame is pivoted to an arm on the top of the column. The copy-holder is fastened on a table at the tail end of the arm, and a pointed styles at the tip of the panto-

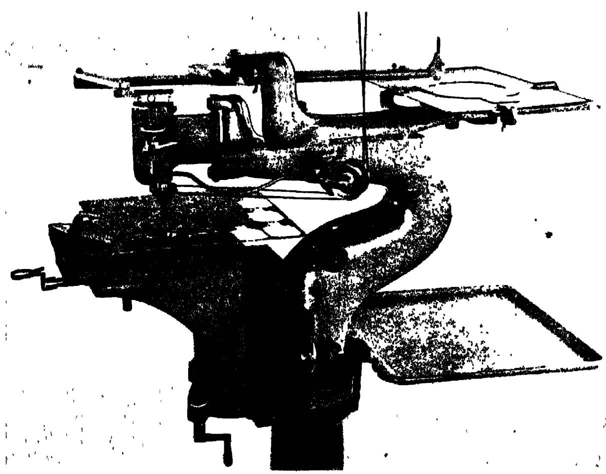


Fig. 141.—Pantograph machine cutting out shapes, under control of a celluloid master copy. (Taylor, Taylor & Hobson, Ltd., Leicester.)

graph lever is caused to follow the copy, the cutter being lowered into the cut by a feed screw. The pantograph can be altered, to graduations, to make the engraving to any proportion between one-third and one-sixteenth that of the copy.

The copy is either cut specially, when this becomes necessary, or for standard letters and figures sets are supplied and clamped in rectangular frames or circular dials, the latter having the letters engraved in a circular formation.

Profile Grinding Machine.—A different application of the pantograph principle is seen in the profile grinding machine, which is of interest in sheet-metal working of the highest class of accuracy, since it is used in

the production of templets, profile gauges, and various types of forming tools. In this case an engraved copy is not used, but a drawing is prepared to a very large scale, perhaps as much as 50 : 1, this being drawn with a hard steel pin with the very thinnest possible lines, because any deviation in the following of the lines by the steel tracer-pin will result in an appreciable error. The drawing is laid on a board, and as an assistant follows the lines on the drawing, the person actually performing the grinding operation observes the path of cross lines in the field of a

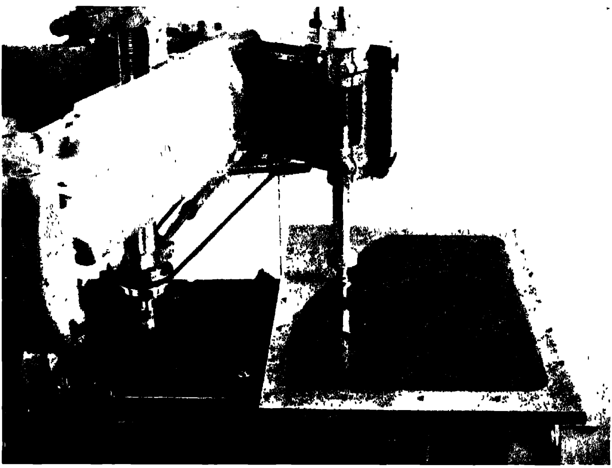


Fig. 142.—Grinding out a die on the pantograph machine, to produce the shape seen lying on the copy (Taylor, Taylor & Hobson, Ltd.)

microscope which is moved by the pantograph. He then feeds the work-holding table so that the piece is traversed towards the grinding wheel, and sufficient ground away until the cross lines, which have a circle at the centre, coincide with the edge ground. The process is continued until the whole length of the profile has been reproduced, the cross of the microscope travelling point for point along the profile to be ground. The grinding wheels are selected of a profile suitable to the shape, as it is necessary to use a straight-faced wheel for some outlines, single or double bevels, or rounded edge for others. Dressing devices are employed to obtain the correct angles or radii. In the first case, a diamond holder is fed angularly by a slide which can be set, by graduations, to the inclination desired, in the other a rocking movement is imparted to move the diamond in a radial path.

Bench Profile Grinder.—A simpler class of machine, without the pantograph mechanism, is built for finishing dies, templets, gauges, and experimental or other sheet-metal parts to a precision degree, on outside or inside contours. The work is hand controlled, manipulating it to scribed lines or a templet, and the grinding wheel or roller projects vertically from a circular table. Pieces can be finished quickly and accurately, instead of filing or stoning, and angles of clearance may be accurately adhered to. The machine is enclosed in a cast-aluminium housing, containing a motor running at 3,450 r.p.m. and belted to the grinding spindle, which makes 20,000 r.p.m. The spindle also has a reciprocating motion, for the purpose of increasing the rate of cutting, preventing uneven wear on the wheel, and improving the finish. The table can be raised or lowered to the extent of $1\frac{1}{4}$ inches, and embodies a tilting adjustment that can be set accurately by a sine bar, giving angular settings up to 5 degrees, at different table heights. All the working parts are below the table, so that the work is always plainly visible, and as the machine is easily portable it may be placed anywhere as convenient. The diamond dresser clamps to the tee slot in the table, and is made with a swivel joint for setting. The weight of the outfit is 85 lb., and the table is 10 inches diameter. A $\frac{1}{4}$-h.p. motor does the driving. Wheel diameters are $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ inches, in lengths of $\frac{1}{2}$, $\frac{3}{4}$, 1, and $1\frac{1}{4}$ inches.

The alternative to some such special machine is to employ a jig saw with attachment to carry oilstones by means of which thin pieces or dies may be trued up smoothly and accurately, either at right angles, or with draft, by tilting the table. A range of oilstones can be purchased for this purpose, in round, square, and triangular sections. Preparatory filing may have to be done in many cases after the sawing out has been effected, but the stoning method is, of course, the only way when dealing with hardened pieces.

CHAPTER 8

POWER PRESSES

ALL the multitudinous operations which are capable of being performed by dies necessitate the employment of a great many types of presses. There are, of course, differences as regards size, length of stroke, width of material admitted, number of strokes per minute, pressure imparted, and mode of operation, by hand, foot, or power. Complication in design begins to arise when extra movements are required, as, for example, in double-action drawing-presses, in which a grip action is applied to the blank , or when an extractor mechanism is necessary. Mechanical feeds are sometimes in the nature of additions to standard types of presses, but many specialised examples occur in which practically the whole machine differs from ordinary construction. This automatic feeding of strip or sheet is effected either by a slide or pusher action, by rolls, or a rotating dial or drum. Furthermore, composite feeds often add to the amount of detail in a press, the stock being fed by two systems, in different directions, and multiple-die presses must have a transfer mechanism to pass the work from die to die for the successive operations.

Types of Press Work.—A concise survey may be given of the principal forms in which presses are built, in order to understand the reasons for certain constructional variations. The size, power, and general shape depend on the dimensions of the dies used, and the character of the operations Much bigger jobs of press work are done now that the demands of mass-produced cars and other products warrant the cost of the powerful presses and expensive dies required, but the alternative of making smaller sections and building up the whole by riveting or welding is often chosen, the latter course being the only one when the numbers wanted are relatively few. In some articles, different sizes of central or outlying portions may be assembled according to the variations in dimensions which are requisite so that this sectional method of obtaining similar kinds of objects is the most convenient and economical. Some firms who do a considerable amount of press work may find it necessary to put out their largest pieces to stampers who possess the plant suitable for such production. Again, there are numerous smaller items of a standardised type which can be purchased to better advantage from the pressings manufacturers. Therefore, in choosing press equipment, due consideration must be given to these matters.

Hand Presses.—Two classes of hand-actuated machines are made, lever and screw, the former being employed only for very light duties.

Above a rectangular base, the top die platen is moved by means of a plunger sliding in a bracket fixed to a pillar secured in the base, and a lever with spring-return motion does the forcing down. Much greater power is delivered by the fly press, which depends for its impetus upon a multiple-thread screw turned by a fly or handle carrying weights, or by a flywheel. The tool ram is thus sent down with much force, and a great variety of processes can thus be carried out cheaply. Either a swan-neck or double standard form is adopted for the frame, and it may be bolted to the bench or to cast-iron legs. Screw blocks or poppets hold the bottom die, or clamping plates are used in some instances. A square-section ram is the most usual, but a wide, flat style is chosen when long dies have to be mounted for multiple punching, blanking, or forming, or large round or square dies for meter parts, keg ends, shovels, and so on. The bed may be in the form of a bar instead of a flat table, for supporting box-shaped objects, tubes, etc.

Data relating to sizes of a series of fly presses are as follows, all dimensions being in inches :

Largest blank stamped	2	3	4	5	6	7	8
Stroke	3½	3¾	4½	5	5	5½	5¾
Distance from bed to guides	5⅝	6	7	7½	8½	9	9
Centre to back . . .	3	3½	4½	5½	6	6½	7
Width across base .	10¾	13½	14½	15	17	23¼	24½
Diameter of screw .	$1\frac{7}{16}$	1¼	1¾	1⅞	2⅛	2⅝	2⅜

Foot Presses.—A good many types of blanking and other dies are worked in foot presses, which are convenient because of the freedom of the hands, enabling output to be increased over that possible on a hand machine. Some have lever connections from the pedal, while in others a pendulum swings backwards when stepped on, and thus moves the slide down. Generally the slide works in a fixed standard, but for special purposes the head may be adjustable up and down a pillar, so as to accommodate different thicknesses of dies and other tools. The slide-ways should be long, so as to control blanking dies accurately. A stroke of from 1 inch to 2 inches is provided in different sizes of presses of this type. The bed is of quite small area for many purposes, but large for specific functions, such as cutting blanks for oil tins, the press for these having an oblong bed with a 16 × 22-inch hole in it.

Bench Power Presses.—The tendency is always towards displacing the foregoing types in favour of small power-driven presses, one of which will do two or three times the quantity of work in a given period. Bench machines are miniature editions of the bigger ones, as regards frame, drive, slides, and table, and they can be of either fixed or inclinable pattern. Two or more may be placed on the bench, for convenience of quick handling when doing succeeding operations ; or two may work simultaneously on opposite ends of a long strip or plate for a duplex operation. Any press could be bolted to a cast-iron stand with

tray top if desired. The following is the specification of a small bench power press:

Maximum pressure	4 tons
Stroke . .	$\frac{1}{4}$–1 inch
Flywheel revolutions .	150 r p m.
Power required .	$\frac{1}{2}$ h p
Table surface .	6 × 9 inches
Maximum distance, bed to ram	6 inches
Centre to back .	$3\frac{1}{8}$ inches
Weight .	275 lb

A hand-operated clutch is arranged for the control, and an electric motor with vee-belt drive (Fig. 143) offers an alternative to a belt on the flywheel. In many machines preference is given to pedal control of the clutch. The heaviest of what are classed as bench presses gives a pressure of $5\frac{1}{2}$ tons at the bottom of the stroke, and takes 1 h.p. to drive.

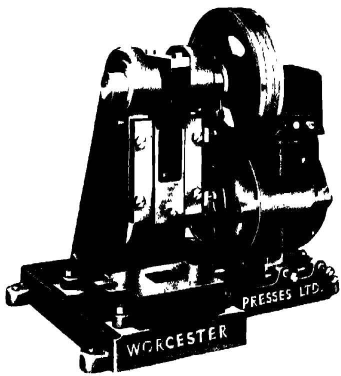


Fig 143 – Two-ton bench press driven by $\frac{1}{2}$-h p motor. (The Mining Engineering Co , Ltd)

Open-fronted Presses.—An extensive range of machines of this type is available up to large dimensions, built on the same general principles as the small types just described. In theory the gap form is wrong, because of the tendency to spring when the pressure comes on, but this defect has to be countered by massive construction, and by choosing a press suitable for the character of the work. The arc movement which occurs when the frame deflects may not cause any harm on some jobs, such as those where bending or pressing is done, or large clearance exists between a blanking punch and its die. But a very fine die possessing small clearance suffers very quickly, and will need regrinding prematurely. The same outfit used on a larger or stronger press will often produce a greater volume of work without requiring attention, although it must be noted, as against this, that the increased depth of gap in a bigger machine tends to reduce the apparent advantage to be derived. The addition of tie rods is a compromise which acts effectively if too much is not expected from them. Being elastic, they will stretch under excessive tension. There is also a danger, when tightening them up, of throwing

the faces of the ram and bed out of parallel. This risk is avoided in a type of rod which is attached to the head of the frame by an eye, while at the tail there is a collar acting as a distance piece, so that when the nuts are tightened the frame cannot be sprung.

The advantages of the open-fronted press in regard to ease of manipulating stock and of attaching automatic feeding devices therefore makes it a favourite for all purposes where it is not more desirable to employ a double-sided or four-post style, which is not subject to one-sided deflection.

Fig 144 -- Sixty-ton open-fronted press having five inclined positions of setting.

Inclined Presses.—A large proportion of the open-fronted machines are inclinable, in order that the stampings or scrap may fall away, the usual practice being to bolt the press to a base on which it can be tilted as desired through the medium of bolt slots or holes (Fig. 144). Some presses are upright only, a suitable attitude for many purposes, and for use with certain types of automatic feeding mechanisms.

Modifications in Open-fronted Press Designs.—A number of standardised models are built, but modified frame and bed arrangements are necessary for certain functions, chiefly to afford abnormal capacity, or to deal with classes of work that cannot be handled on the standard models. The obvious variations are those of increased depth of gap, increased height from ram to bed, and larger area of the latter. Greater throat capacity is required for taking some kinds of wide dies, or to pierce holes in the middle of large sheets. Thus a press, which for ordinary duties will have a throat depth not exceeding about 10 inches, has this increased to 24 inches for the reasons specified. Abnormal distance from ram to bed is essential when operating certain classes of dies. Adjustable tables, however, meet this demand, and enable any kind of blanking, piercing, forming, or other dies and subpresses to be accommodated on the same press. One or sometimes two screws elevate the table, and it is

locked rigidly by bolts or a taper gib. The degree of adjustment ranges from 4 inches to 15 inches in different sizes and types of presses. When the table is removed, a horn can be fixed in a hole in the standard, for grooving, punching, or other functions; a swing table pivoted on a bar being sometimes employed to save time in effecting such a change. Some presses have a horn cast on or attached in the frame, and no flat table. Or, to permit various horns, brackets, subpresses, bolsters, etc., to be fixed, a plain, flat, vertical facing with a ledge and bolting holes may be cast on the frame. A combination arrangement comprises a cylindrical flatted horn, and an angle-bracket form of table below it, carrying rollers to support a motor rim. The table floats on springs, so as to keep the rim free of the punch (which is fixed in the horn), enabling rotation to be given to the next position. The die descends and presses the rim on to the punch, which pierces and countersinks it.

Fig 145 —Hundred-ton double-sided press equipped with hydraulic cushion

An extra large table is necessary for taking certain dies, and will have a slide for withdrawal and return, as when working wiring-dies. Many of the automatic feeds require long tables to hold them, especially in the case of presses for rapid production of blanks from large sheets and in multiple-die types, in which the stamping is automatically transferred from die to die.

Double-sided Presses.—There being no arc spring in the double-sided frames, such machines (Fig. 145) can be employed for the heaviest duties without deflection occurring to have an adverse effect upon the dies. Provided the loading is fairly central, the only effect is that the frame stretches vertically, which is of practically no moment in a properly designed machine. The massive construction resists this action, the heaviest sizes being reinforced by high-tensile steel rods shrunk in place. The tension thus imparted must be carefully calculated so as to exceed that of the working load, yet not be so excessive as to strain the frame

unduly. In the Bliss presses, apertures are cast in the uprights for the purpose of applying a blow torch. The rods are put in and the nuts tightened, after which the uprights are protected locally by asbestos and the torch applied to heat the rods, usually about twenty minutes being long enough. The expansion is measured by a gauge between the lower nut and the frame, then the nuts have to be turned by an amount given in a table, so that when cold they will be under the proper tension.

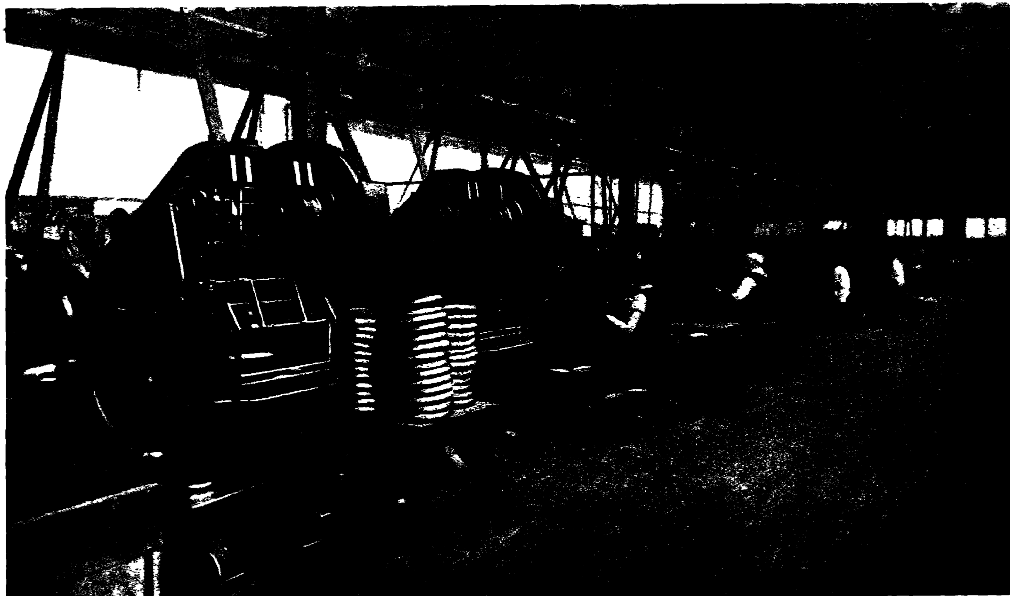
Frames.—The style of frame in a double-sided press is varied according to whether single- or double-crank motion is adopted, or double action for drawing operations has to be incorporated ; it depends also on what kind of bed is required. Double cranks (Fig. 146) are employed for powerful presses having wide slides, such as are used for cutting large blanks, pressing panels, doors, covers, and other objects. The pressure is distributed in this manner so as avoid tipping and injuring the dies, or producing imperfect work. In exceptional instances, four cranks move the slide, by means of two shafts, and the tipping tendency is still further reduced, particularly when dies have irregular contours.

A double-action press has cam or toggle mechanism which forces down an outer slide or pressure plate, and gives it a dwell on the blank during the drawing process. The toggle motion (Fig. 147) differs from the cam, in that it transfers the pressure to the framing.

The bed of a double-sided machine is circular or rectangular, with two or more T-slots, and takes a bolster or a special die mounting as required. Generally the bed is solid, but a spring-compensating type is fitted for special reasons, to apply a steady and uniform pressure to work of varying or irregular thickness. In one arrangement the tension of the springs can be regulated by turning a handwheel. The slide movement previously mentioned, introduced to enable dies to be withdrawn, is manipulated by handwheel and two pinions for heavy work, a safety catch being fitted to prevent the press being started until the die has been racked into correct position.

Differences in bed design are sometimes necessitated when automatic feed is added, although it may be mentioned that this apparatus occurs much more among the open-fronted presses. The advantages of the double frame, however, recommends it for fast work and long die life. Some kinds of feeds pass the stock from front to back, others laterally, in which case the standards are cast with apertures to permit of this being done, the roller brackets being bolted to the outside faces. When using a rather large dial feed, it may be necessary to attach a supporting bracket to the front of the bed. Brackets are also required to carry large pulleys which drive friction bands to feed sheet for some classes of multiple-die stamping.

The inclined position, as with open-fronted presses, is chosen for purposes of letting work and scrap fall away, and also to give gravity feed to a sheet towards multiple dies. The press frame is bolted to a sloping base of fixed angle, or adjustment is afforded by a tilting motion, regula-



Valor Co., Ltd

LINE OF INCLINABLE PRESSES AT THE WORKS OF THE VALOR CO., LTD., BIRMINGHAM.

(Pressed Steel Co., Ltd.)

A HEAVY PRESS BAY

General view of the heavy press bay in the works of the Pressed Steel Co. Ltd., Oxford. Some idea of the size of the machines may be gauged from the large automobile floor panels seen stacked in the foreground.

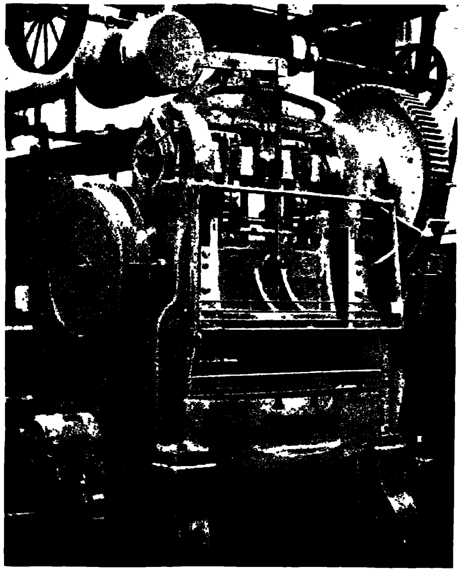


Fig. 146 —Hundred-ton double-crank press for blanking and other operations (Hordern, Mason & Edwards, Ltd

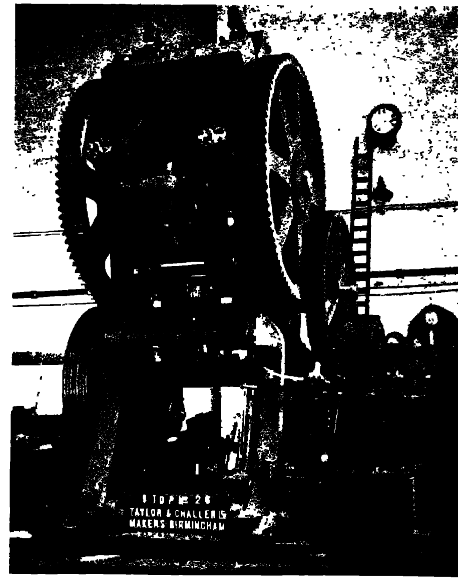


Fig 147 —Double-action drawing press capable of drawing an article 38 inches diameter by $9\frac{1}{4}$ inches deep.

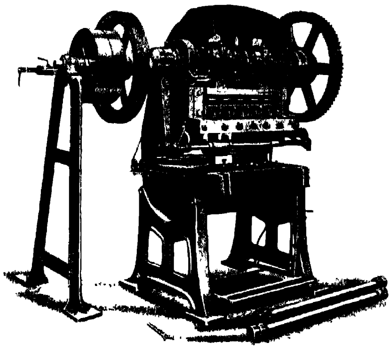


Fig. 148 Multiple five-slide press (Lee & Crabtree, Ltd)

ting bolts coming from the base at the rear, and passing through lugs some distance up the frame, locknuts controlling the setting

Extractors.—Either of the two main types of presses described may be equipped with an extractor or ejector which pushes the article up from the die, whence it is picked off, slides down, or is blown away by an air blast The rise of the ram operates the extractor plunger, by means of side rods, coupled to a crossbar through which the plunger is adjusted by a handwheel and locked by a nut. Another system is to move a rocking-lever transmission from a crank on the main shaft, a lever on a shaft underneath the bed pushing up the extractor rod.

Multiple-die Presses.—The use of a gang of dies serves for either of two functions, viz. to blank a large number of units rapidly, or to carry out successive operations on one piece. The press for either purpose must be wider than normal (Fig. 148). In a specimen for cutting, drawing, and stamping, fourteen dies are disposed in two rows, placed to cut in staggered fashion to use up the

Fig. 149—Six pressings are made simultaneously on this Rhodes' automatic press.

sheet with the minimum of waste. The feed band is actuated by a set of ratchets and pawls which hold the sheet firmly while cutting takes place. An auxiliary skip feed prevents the cutting of half blanks at the ends of the sheet, so that the dies are not subjected to uneven wear. After the pieces have been blanked and drawn, an ejector pushes them above the feeding level, and a sweeper carries them off the dies to a box at the back.

An automatic five-operation press is constructed with a revolving feed table upon which the stampings are placed, after they have been drawn to the first shape in an ordinary press. They are automatically transported from die to die by means of sliding grippers worked by a cam at the end of the crankshaft in synchronisation with the operations. The five rams have a stroke of 7 inches, the machine being of the open-fronted pattern, fitted with three tie bars. Fig. 149 shows a high-production press for tops and bottoms of cans, etc.

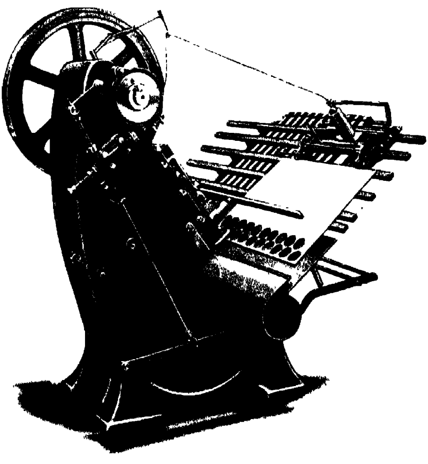


Fig. 150.—Semi-automatic sheet feed press. (Lee & Crabtree, Ltd.)

Stagger-feed Presses.—A mode of cutting or stamping large numbers from a sheet is through the medium of a stagger or zigzag feed, using one die, and shifting the sheet after each stroke so that as much as possible is used, with the minimum waste. All the movements are automatic, and when the sheet is finished, the carrier returns to the starting position and the press stops. Different divisions, to suit various cutting diameters, are obtained by varying the choice of change gears and controlling racks. The saving of sheet by this zigzag method amounts to as much as 20%. A semi-automatic type is seen in Fig. 150.

Automatic Strip-feed Press.—A variation on the continuous feeding method is applied to strips, used in stamping tops and bottoms for tins. A combination of a suction lift and a carrier feed acts to take the strips from a pile in a magazine, the sequence being as follows. The suction

feed takes hold of the top strip and lifts it slowly, placing it on the feed table before the suction lets go. The suction feed moves at one-sixth the speed of the carrier feed, ensuring smooth, easy delivery of strips to the push bar. The latter grips the strip and feeds it through the die. Finally, the stampings fall to the back of the machine, and the scrap metal is thrown clear of the press by an ejecting arm as each strip is used up. Different change gears are set up to vary the number of blanks cut from a length, and the feed fingers also require an adjustment. An attachment to this press takes the blanks through a curling machine, and stacks them in a pile.

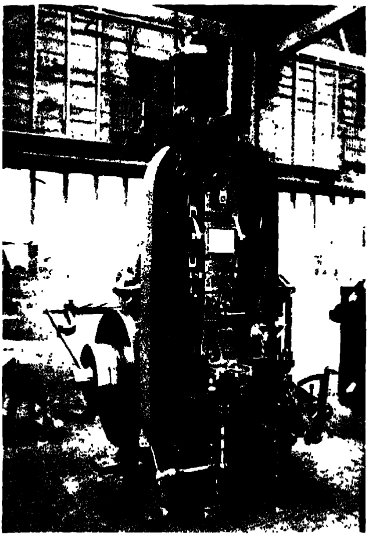


Fig. 151 —Taylor & Challen coining press, giving a pressure of 250 tons. The top die is carried in a hammer lever instead of in a slide.

Coining Presses.—A powerful type of press (Fig. 151) is utilised for coining and embossing, requiring great pressure to bring out designs, or to finish surfaces accurately. Not only coins, but decorative plates, panels, parts for jewellery, silverware, dials, spoons, forks, knife-handles, etc., are finished in these presses, which are relatively small and compact, but exert pressures as high as 3,000 tons. The pressure required to stamp a coin may reach 125 tons per square inch. The action being different from that required in other kinds of presses, *i.e.* a rising load attaining its maximum at the very end of the stroke, a knuckle-joint transmission is the best. In this, the connecting-rod from the crankshaft moves in a horizontal direction to push the central pin that straightens out the knuckles. The length of stroke is from just under an inch to 3 inches in different sizes of presses. The massive build demanded is obtained by making the frame in one casting, and in the larger sizes reinforcing it by four stout tie rods, fitted by shrinking. Cold pressing, swaging, and forging, which hardly come within the scope of these volumes, are also executed on knuckle-joint presses. For hand operation, heavy styles of screw fly presses are made, to strike coins and medals. One such has a 6-inch diameter screw, and a 5-foot wheel, weighing $12\frac{3}{4}$ cwt.

Friction Screw Presses.—A coining action is also furnished by the power-driven screw presses, which give an intensive blow at high speed. These machines are used for striking medals, tokens, checks, sharpening up patterns and lines on drawn objects, stamping, planishing, and embossing panels, trays, salvers, and so on, besides which they can be employed for hot brass pressing. The general construction is always similar—a double-column frame, and a large flywheel with friction-band on top of the

Fig 152.—Heavy friction-wheel screw press of 175-tons power.

massive screw, driven by friction disks on an overhead shaft. The intensity of the blow is controlled by adjusting the height to which the slide is allowed to rise; the longer time the flywheel has to gain speed, the more effective the blow. The slide stops automatically at the top of the stroke. The smaller machines may be open-fronted, though the big ones never. Particulars of a light open-fronted design are: capacity 7 tons, stroke $2\frac{1}{2}$ inches, screw $1\frac{1}{2}$ inches diameter, friction-disks 10 inches diameter, friction-wheel 8 inches diameter. The biggest presses

take from 12 to 15 h.p. to drive. A 250-ton machine has an 8⅝-inch screw, stroke of 16 inches, and height from bed to ram (when up) of 35 inches. It is usually most convenient to drive such a press from a motor located on a bracket below the pulley on the shaft of the disks.

Extending Presses.—A specialised form of press is built for extending, reducing, or tapering operations, dealing with shells and cases already drawn by ordinary presses. A narrow type of double-standard press is used, or a horizontal design instead, the length of stroke ranging from 12 inches to 45 inches. The latter limit occurs on a horizontal screw press for extending large brass cartridge shells in successive stages. There is a punch at either end of the screw, so that shells are drawn alternately

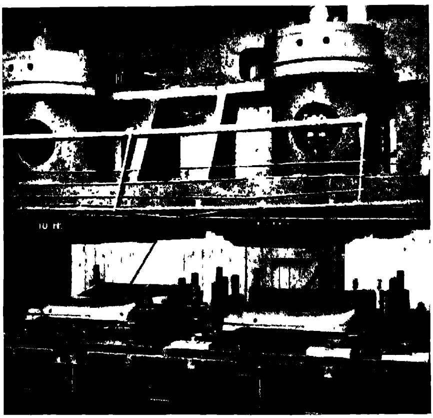


Fig 153 – Radiator cowls being pressed four at a time at the Austin Motor Works.

on each punch as the screw is reversed. On the return stroke, the punches tilt up automatically to permit of feeding. The rate of travel of the screw is 75 inches per minute. The mode of feeding on the vertical presses is by hand placing, or pushing the shells along a chute to position, the dial-feed being best when it can be applied. The turntable is indexed by an escapement movement, and there is no free position, and thus no danger of the punch descending until the proper position has been reached. Feeder fingers deal with the cases in some of the horizontal machines, taking them from a chute down which they roll, and transferring them, one at each stroke of the press, to the die position.

Press Guards.—Automatic feeding of stock and partly finished pieces does not involve any risk to the attendant, as the material goes through

without attention, or a dial enables the supply to be maintained without the hands having to come near the tools. In those other cases where hand feeding must be done, a guard is essential for safety. Several types are manufactured, mostly in the form of a netting or grill covering the lower part of the press An exception occurs in a style composed of three strips bent to horseshoe shape, and pivoted in such a manner that they come down like a visor in front of the descending punch ; as this rises, the strips lift sufficiently for the insertion of the blank

A sliding grill moving along a rod in front of the die makes a simple guard, being thrust along by a lever actuated from the crankshaft, and drawn back as the ram rises. Another pattern has grills at the sides of the table, and in the front a guard is hinged, and swung by mechanism connected to the crankshaft or other moving part (refer to Fig. 146). This guard is a combination of an inner and an outer frame, and the latter moves outwards when the operator's hands are in danger, and consequently obstruct the swing of the] inner frame, and forces the hands to a safe position. A further development is that of connecting the guard to the press-operating pedal, so that the clutch cannot be thrown in unless the guard has been closed.

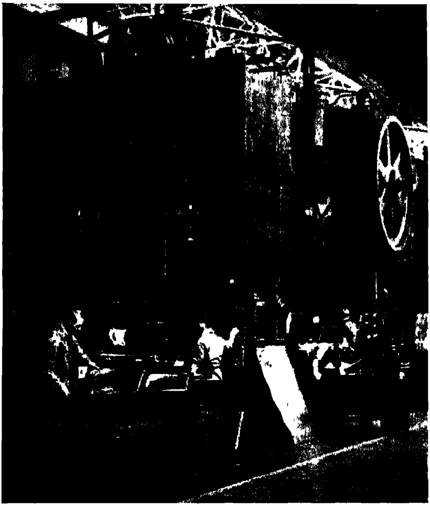


FIG. 154.—Modern hydraulic Clearing presses tooled-up for producing automobile door panels. (The Nuffield Organisation.)

An automatic action takes place in the Schuler guard, which rises in front of the dies before the press starts. The sequence goes thus : The operator releases a pawl with his foot, whereupon the wire guard closes upwards, and becomes automatically locked, and only then is the clutch engaged. On completion of the down stroke the guard unlocks, and opens, and the disengaging tappet comes into action to throw out the clutch. A device then comes into operation, releasing the pawl from the treadle, and engaging the pawl, so that the wire guard is held open. The

slide can never come down until the guard has a free course to reach its protective position. The risk of accident through failure of the clutch mechanism, or breakage of the guard, is eliminated because a spring engages the clutch, and if this spring should become so weakened that it could not raise the guard to the safety location, neither could it engage the clutch. By retensioning the spring, the defect would be remedied. The result of the breakage of the spring immediately after the engagement of the clutch cannot affect the further automatic sequence.

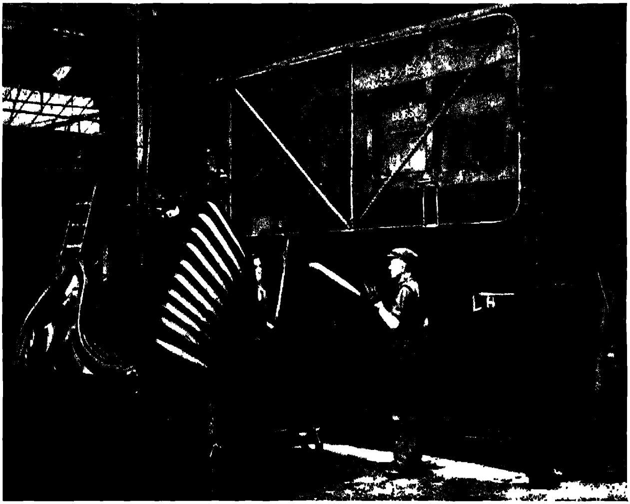


Fig. 155.—Some idea of the size of the tooling employed for automobile body work can be gained from this view. (Vauxhall Motors, Ltd.)

Photo-electric Guards.—A recent development in the design of press guards is the photo-electric model shown in Fig. 157. Although in this particular illustration it is fitted to a press brake, it is equally applicable to other sheet-metal machinery, including guillotines, presses, and many other types of machines. It may be applied to any hydraulic or mechanical press employing air- or hydraulically-operated clutch mechanism, and it can be combined with any of the standard types of motor-driven presses, in which case it is necessary to fit electrically-operated clutch trip mechanism.

The design of the guarding system is extremely simple—a fact which minimises chances of failure, and the equipment is so interlocked that in

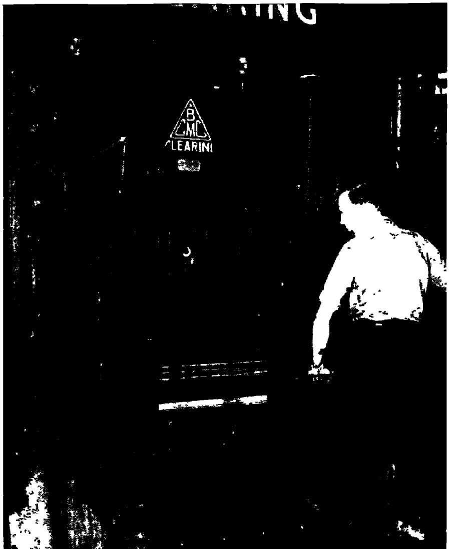


Fig. 156.—This view of an hydraulically-operated press illustrates one method of guarding the operator from injury.

Fig 157.—A press brake equipped with a photo-electric guard. Key: —(A), projector, (B), receiver, and (C), clutch-control mechanism. Above the projector is a red warning light.

the remote event of this happening the machine is rendered inoperative. In addition, a clearly visible red light provides constant warning when the machine is " alive " and capable of operation by actuation of the appropriate foot control.

Although other types of photo-electric guards have been developed in the past, this particular system differs in the fact that a " curtain " or " barrier " of light is employed instead of a beam or beams. Consequently, there is a complete absence of " blind spots " through which the operator can inadvertently insert his hands. The thickness of the work, however, is not sufficient to operate the guard system. On the right-hand end of the machine, well clear from the operator, is a pillar carrying a " projector " incorporating several light sources shining through special diffusing lenses, the number of which varies according to the depth of " curtain " required to cover the opening of the tools, with a large safety margin.

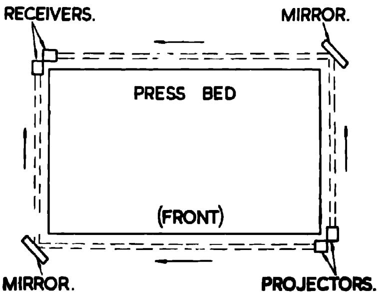


Fig. 158. Diagrammatic lay-out of a photo-electric system guarding four sides of a press

In a similar unobtrusive position at the other end of the machine is the photo-electric cell " receiver," containing condensing lenses which concentrate the light barrier from the projector on to a number of photo-electric cells. The apertures of the cells are so placed in relation to the focal length of the lenses that only light from the projector can reach the cells. This prevents variations in sensitivity likely to occur from changes in extraneous light, such as would happen when the shop lighting is switched on or off, or from variations in daylight conditions.

The receiver is connected to a control unit incorporating one or more relays which are energised when the light carrier is uninterrupted ; in this condition the machine will operate in the normal manner by pressure on the foot lever or any other standard type of control. However, should the operator interrupt the beam, *i.e.* move part of his body towards the danger area, the relays are de-energised and it is impossible to operate the machine even if the controls are depressed. In a similar manner, the machine is instantly rendered inoperative should the light barrier be broken whilst the press is actually in operation. This latter feature, however, does not apply in the case of presses which are so designed that they must complete their operation cycle once it has started.

The design of the clutch mechanism varies according to the make and type of press, but in the particular example illustrated in Fig. 157 it has

been possible to neatly enclose the equipment in a small housing (C). When the machine is not in use, the guard system is disconnected by the main switch controlling the press motor; the red warning light is then extinguished, thus denoting that the machine and guard are out of action.

The above system, of course, protects only the front of the press, and this, in most instances, is quite adequate, as the ends can usually be enclosed with ordinary fixed guards without any loss of efficiency. Certain types of machines, however, are open on two or more sides, as in the case of hydraulic presses, which generally require protection on all four sides. Fig. 158 shows how this problem was overcome to guard an hydraulic press measuring 10 feet 8 inches long by 4 feet 3 inches deep, and the very ingenious scheme adopted to avoid the necessity of employing four separate units, *i.e.* one for each side.

The front of the machine is guarded by a photo-electric unit situated at the right-hand corner; this projects a 16-inch deep by 2-inch wide barrier of light across the opening, the depth of the barrier being sufficient to provide an ample margin of safety when the press is opened to its maximum position. The light falls on to a $16\frac{1}{2}$-inch by $4\frac{1}{4}$-inch mirror pedestal-mounted in a pressed-steel housing situated at the front left-hand corner of the press, the housing being adjustable to permit alignment with the rays The mirror is fixed at 45° to the direction of the beam, and consequently the light is reflected along the side of the press, falling on to a receiver mounted at the rear left-hand corner.

A second unit projects a light barrier along the opposite side of the machine on to another mirror set at 45°, this reflecting the beam across the rear to a second receiver. By this means all four sides are fully protected by two units Interruption of any beam causes the press mechanism instantly to stop, thus rendering the machine foolproof and safe even if any of the operators are hidden from the man at the controls.

CHAPTER 9

BLANKING PRESSES

BLANKING is an expression referring to the particular press-punching process which cuts out a shape by means of a punch which enters a die on which the sheet lies. The operation may be confined to that of obtaining a piece for direct use, or one to be drawn or otherwise formed by further processes. A considerable proportion of certain classes of products is blanked and drawn on the same press, and may be further treated at the same stroke, indenting or lettering, etc, being done. Some blanking dies are very intricate in shape, and only the correct type of press is able to use them without causing premature wear or damage to the cutting edges. A good many considerations must be taken into account when making the choice of machine, size of blank for example, the pressure required according to the kind of metal and its thickness, what other operations have to be effected at the same time, and whether automatic feeding is to be applied.

It should be noted that the following data refers only to mechanical presses and not to the hydraulic types now often employed for larger blanking and drawing operations Nor does it cover the specialised so-called hydraulic "rubber presses" used for blanking and forming light alloys in the aircraft industry For information regarding the latter equipment reference should be made to Chapters 10 and 8, Volumes II and III.

The two main difficulties in regard to blanking consist in avoiding deflection of the frame at the time of penetration (which would cause the die to deviate from its correct path), and reducing the dangerous snap back which occurs when the load is released at the moment that the shearing action is completed. These problems are determined by the type of press employed, its stability, whether tie-rods are fitted, or if it is double-sided. A factor of great importance lies in the amount of shear given to the tools; this enables the work to be performed at a lower pressure, because of the gradual attack of the cutting edges, and the break-through does not take place suddenly, so that there is no whole release of the pressure, and therefore no spring of the press frame. Even a small amount of shear is beneficial in this latter respect. It is always desirable to use an amply strong press, the more so as fast production on large quantities is essential, hence a double-sided pattern will be chosen in many cases to give high speed with long die life, or a more powerful size might be selected for continued strenuous duty than that which would be deemed suitable for short runs with similar tools. The requirements naturally vary, depending on the material, whether it is a soft or hard metal. Other conditions being equal, a considerable difference may occur in the working of the dies if their clearance is insufficient.

It is a question of primary and secondary shearing. When the proper amount of clearance has been given, the sheet becomes deformed until finally it fractures, and this event should happen simultaneously from the opposed cutting edges of punch and die. With insufficient clearance the metal becomes torn by a secondary shearing action, leaving a ragged edge, and the effect on the press is that it has more work to do, the pressure necessary being spread over a longer period. This secondary shearing action increases as the clearance decreases below that which is necessary.

Main Types of Blanking Presses.—The brief résumé given in the previous chapter indicates the principal types of presses employed for various classes of operations. Those specifically for blanking, or blanking and drawing, include many different designs, open-fronted and double-sided, single-action and triple-action, and with hand or automatic feed. One of the largest machines, having four cranks, and exerting a pressure of 560 tons, cuts out and pierces turbine rotor blades, 28 inches across the flats, and 16 s.w.g thick. The weight of the tools is 43 cwt. The C-frame or open-front machine is built in sizes from the little bench models to large geared presses of about 200 tons pressure. The usual disposition of the crankshaft is parallel with the face of the frame, but many, including the punching presses, have it lying at right angles (Fig. 159). The chief functional differences are, whether direct or geared drive is used, and whether the stroke is fixed or variable. Single or double reduction gearing is fitted, according to the heaviness of the duty demanded.

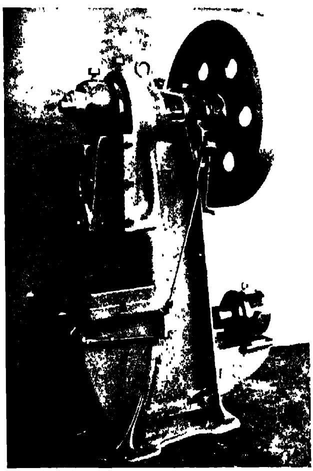


Fig 159 —End-wheel type of press, which gives a rigid style of frame (Schuler)

Automatic Clutch.—The mechanism whereby a press slide is moved may be studied in Fig. 160, this being the style fitted to Taylor & Challen blanking presses. Normally the flywheel rotates freely on the crankshaft without affecting it, until the starting lever is depressed, by means of a handle or pedal. This lever is connected by a light rod to a double lever A, one end of which acts upon a lug B fixed to the clutch rod C. When the starting lever is depressed the lever A, acting on B, causes the cam plate D to recede from the flywheel, and in doing so allows the key F to shoot by spring pressure into a notch in the hardened-steel bush E, fixed in the flywheel. The shaft and wheel now rotate together, and so impart the

movement to the ram. While the crank is returning on its upward stroke the spring on C pushes the cam D into its former position, and by the time a complete revolution has been made the key F has receded into the shaft again. The crank is thus stopped at the top of the stroke, and the flywheel alone continues to revolve until the starting lever is again moved. The catch G prevents this slide from accidentally tripping on over-running. As will be seen, on this catch is fixed the locking arrangement used when tool-setting ; before this is attempted the knurled disk seen on G should be given a half-turn to the right. This will lock the clutch cam in its off position, and so prevent the possibility of the press acting. The tool-setter may now set his dies by turning the crankshaft in its normal direction without troubling to remove the belt from the flywheel. Holes are provided in the brake disk on the end of the shaft to enable it to be turned

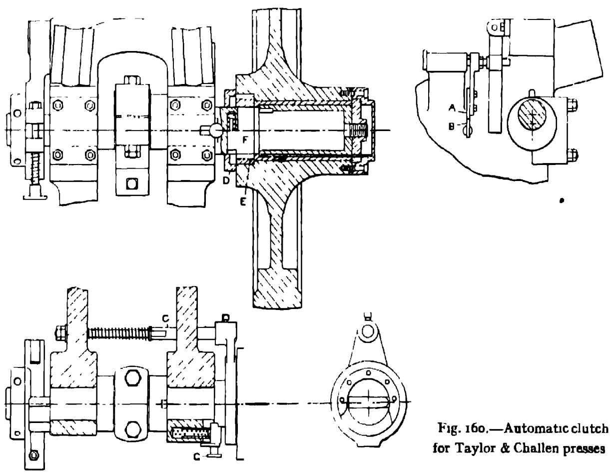


Fig. 160.—Automatic clutch for Taylor & Challen presses

If the shaft should fail to act, owing to the punch jamming on extra-heavy work, the cam D should be moved back by the hand or foot lever, then with a strip of steel the key F has to be pushed into the shaft, allowing the cam to move over. The flywheel is now run up to speed, the clutch engaged, and the stored energy in the flywheel may overcome the resistance, the crank completing its revolution and coming to rest at the top of the stroke. A one-stroke attachment can be fitted in the form of an extra lever to the right of A. A lug is secured to the crankshaft web, and is timed to push the lever back on the upstroke of the press. This lever in turn moves the striking part of the lever A out of alignment with the projection B on the cam-plate shaft. The spring immediately returns the cam plate

to the off position, causing the press to stop on top dead centre. This action occurs even if the hand lever or pedal remains depressed, and it is necessary to let them go back to normal position before another stroke can be made.

Fig. 161 shows the style of clutch which is fitted to Rhodes' presses, giving complete control of the crankshaft by the flywheel on both the upward and the downward stroke. The bolts open and close simultaneously. When the treadle is depressed, the rod A (Fig. 162) moves upwards, so tilting C and causing its companion lever to swivel the clutch bracket on pin B, releasing the clutch bolt. A stroke of the ram then takes place. The small roller seen on the circular catch-plate strikes the vertical lever C before the stroke has finished, and a second movement of the ram is prevented, even when the treadle remains down. If this roller is removed the press will run continuously so long as the treadle remains depressed. By moving a small lever the clutch can be locked for die-setting, so that a stroke cannot take place.

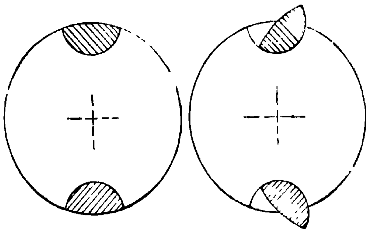


Fig. 161 —Action of clutch bolts on Rhodes' press

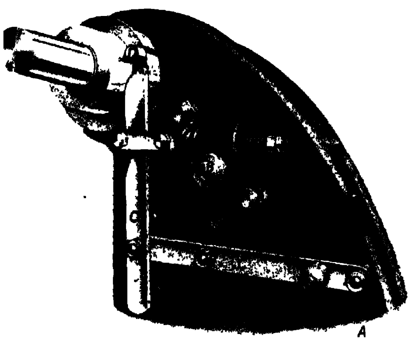


Fig 162 -- Mechanism which controls the Rhodes' clutch

Adjustable - stroke Device. — When different lengths of stroke are required an eccentric bushing is fitted to the crankpin in such a manner that it can be partially rotated to fresh positions and locked positively. There are various methods of effecting this motion, by toothed locking washers, segmental pads, and curved keys. Fig. 163 represents the second-named arrangement as applied to Rhodes' presses, though the first-named device may be furnished when desired. It has the disadvantage of one-sided transmission which is not present in the style illustrated. Here the teeth are on the periphery and the pressure is balanced.

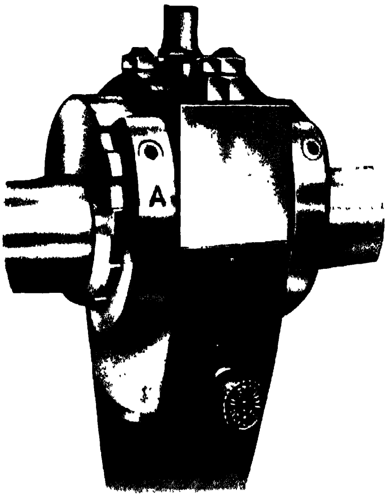


Fig. 163.—Rhodes' adjustable-stroke device

Taylor & Challen practice is as illustrated by Fig. 164. The eccentric bush A is held in position on the shaft by the curved key. To alter the stroke the set-screws are slackened, and the end-plate which prevents the curved key from slipping out is swung away, thus enabling the key to be withdrawn. The shaft and bush can then be turned by means of tommy-bars to obtain the required stroke. Figures are stamped against each keyway on the shaft and bush indicating the length of stroke, so that when two keyways bearing the same figure are brought opposite each other, and the key inserted, the press will run at that stroke. The end-plate C has to be replaced and the set-screws tightened. Examples of the range of strokes provided on three commonly-used sizes of machines are: $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{8}$, $1\frac{5}{8}$, 2, and $2\frac{1}{4}$ inches; $\frac{1}{2}$, 1, $1\frac{3}{4}$, $2\frac{7}{16}$, 3, and $3\frac{1}{2}$ inches; and $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and 4 inches.

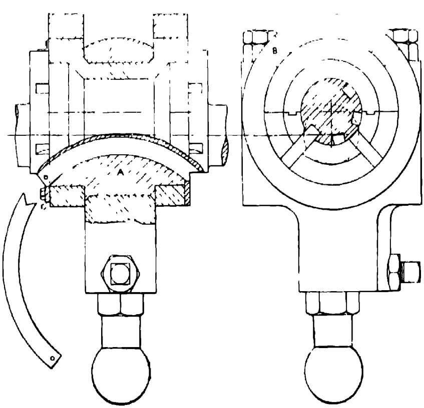


Fig. 164.—Taylor & Challen key and-eccentric stroke adjustment.

The eccentric adjustment on the end-wheel type of press

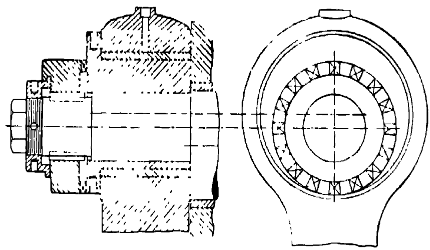


Fig 165 —Stroke adjustment for Schuler end-wheel press

embodies a graduated dial with peripheral notches for locking, and settings to one-hundredth of an inch can be read. For sub-press work a device can be included which gives four definite settings, without affecting the use of the regular adjustment (Fig. 165). The toothed locking ring can be retracted by means of the nut to enable the eccentric bush to be turned.

Connections to the Ram.—The connecting rod, or pitman, which transmits the movement from the crankshaft to the ram has to be attached flexibly to the latter, and this is done by means of a ball end on the screw which goes into the pitman and enables the height of the ram to be altered. After setting, the screw is gripped by a split lug and bolts on the end of the pitman, or a loose cap is employed instead of the split lug. A straight-line construction is the best as preventing any tendency to rock, that is, the centre of the crankshaft and that of the hole in the ram should be in line. In some cases, such as those of the end-wheel designs of punching or blanking presses, a simple pivotal connection is made to the ram, without a ball. This is also the case with the heavy presses using eccentrics cast on the wheel hubs (Fig. 166). The double-crank mechanism requires simultaneous adjustment of both ball rods, this being effected by a horizontal shaft and duplicated bevel or worm gears. The shaft is turned by a tommy-bar, or a chain wheel, while a hand wheel is the alternative in large sizes. The biggest presses have a motor for this service ; thus an 18-inch stroke press driven by a 35-h.p. motor has a

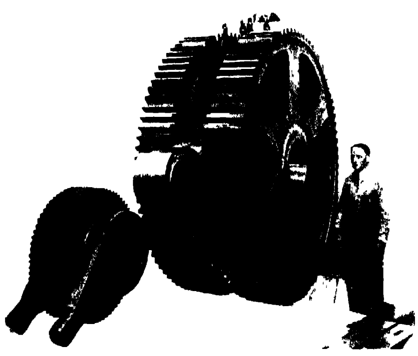


Fig 166 —Gears combined with eccentrics, which give the motion in Wilkins & Mitchell presses

7½-h.p. motor for the slide adjustment, connecting to the gearing by a slidable vertical shaft, through another with universal joints. Fig. 167 shows a press thus fitted.

Slideways.—Correct design and maintenance of the ram slideways is highly important as affecting the working of dies, and their freedom from premature wear or injury. Ample length should be given in order to reduce the tendency to tipping, otherwise intricate dies cannot be operated accurately. The self-guidance of a wide slide is, however, inadequate, hence the reason for the two-crank and four-crank motions, in conjunction with the four vee-guides placed at the corners of the slide. As a security against the risk of the frame springing, many presses include a round or flat tie-bar attached to the faces of the standards. Instead of the usual practice of bolting the adjustable guide strips to the frame, in some large models they are attached to the slide, so leaving the whole area of its base free for the fitting of large tools. In the machines built up from steel plates, the ram guideways consist of iron castings secured with bolts. Fig. 168 illustrates a very strong "ring" frame of steel, and Fig. 169 another plated construction which has rods as guideways.

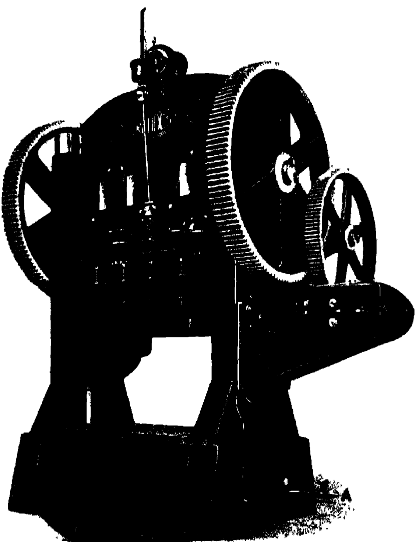


Fig. 167 —300-ton motor-driven press with air-operated multiple-disk friction clutch and air-balanced slide (Rhodes)

Counterbalance.—Many of the bigger presses, of 60 tons and upwards, have the slide counterbalanced by a weight or springs or air. This confers the advantages of smooth action, ease in turning the press by hand when setting the tools, and the punch does not tend to suffer by dropping into

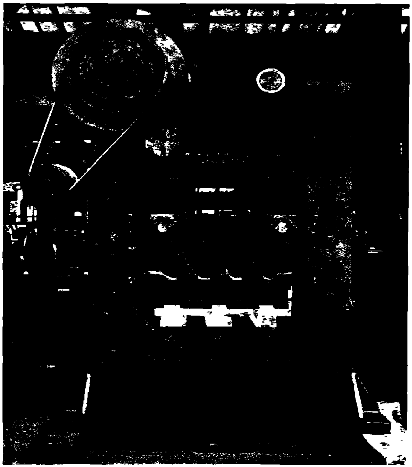


Fig. 168.—Steel-plate "ring" type of frame. (Wilkins & Mitchell.)

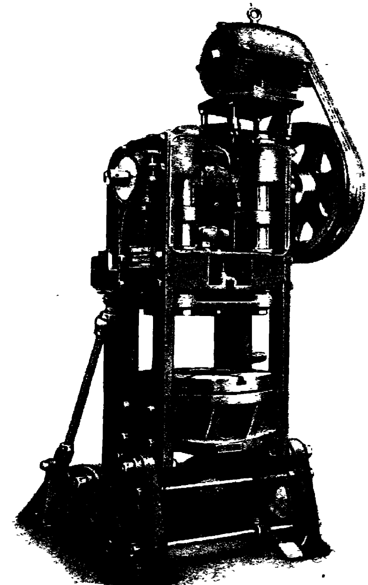


Fig. 169.—High-speed press of steel-plate construction. The openings permit strip feed. (Rhodes.)

the die after the blank has been cut. Several of the Taylor & Challen machines are arranged with rods pivoted at the flanks of the slide, and attached to a pair of rocking levers above the top girder, and the weight is bolted to the other ends of these levers. Another system is that of running cables up from the corners of the slide, over pulleys to a central weight which has only vertical movement. When springs are employed, either two or four casing cylinders stand in front and rear, and rods go down to the slide.

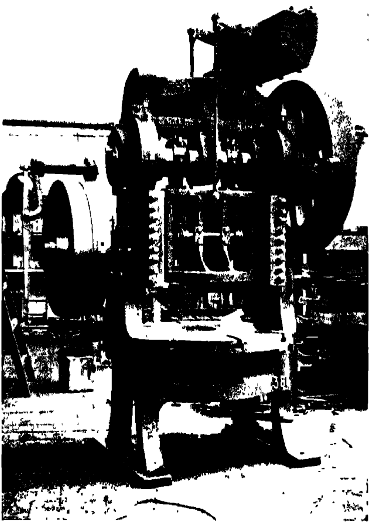


Fig 170 —100-ton double-crank press with balanced slide.

Beds.—A good deal of variety is to be seen in the design of beds for blanking presses, and sometimes the faces of the slides are modified in accordance, such as making them specially wide, flanged, or square. Standard shapes of beds are square, oblong, or round, with two or more slots to fasten the bolster or other mounting. A round or rectangular opening is made at the centre. The bed is extended by flanges for certain purposes, particularly to accommodate automatic feed-roll brackets, and an auxiliary wing may be included to carry straightening rolls. Scrap cutters or scrap winders are other attachments requiring extensions. Poppet screws are fitted to many small presses, and to some of the larger sizes, affording facility for adjustment and fixing, but clamping plates are more commonly employed.

Fittings are located underneath beds for extracting the material after blanking, and also for cushioning the die. The extraction is performed by a spring motion operating a plunger; or a positive mechanical thrust is obtained by means of side rods reaching down from the ram to a cross-bar through which the plunger is adjusted with nuts or a hand wheel. For large diameters a rising plate is fitted to which the extractor plate is attached. In the case of a double-crank press which blanks and pierces rings 30 inches diameter, three extractor rings are provided, two in the top die, and the lower one is pushed up by a plate lifted by rods as described.

Die-cushions are mounted in the beds of blanking presses when combination dies are used. The cushion supplies a counter-pressure to a ring on which the blank lies as it is cut, being held with enough pressure to prevent puckering. The pressure is derived from a rubber block, or a spring, while hydraulic or pneumatic cylinders are largely utilised. If there is no air line in the shop a self-contained outfit is supplied, consisting of a small compressor and an air receiver.

Applications of Blanking Presses.—In view of the large number of various kinds of blanking presses which are available, descriptions may now be given of the diverse applications of these presses, to enable the user to decide which type to select for certain purposes, and how the tools, attachments, feeding, and other equipment are arranged. As previously indicated, many of the standard designs of machines are suitable for a considerable range of duties without modification in the framing or bed, and a special bolster bolted to the latter affords flexibility in arranging dies and other details. It should be mentioned that the T-slots in the bed should be machined out, so that the hold-down bolts take a proper bearing and keep the dies always fixed truly. The bolster ought also to be of substantial form and ample area to withstand the severe pressures to which it is subjected. Quite a lot of specialised mounting can be done by using a thick and enlarged bolster, but, of course, there are numerous instances in which it is essential to have the bed of widened pattern. The open-fronted design often lends itself more freely to this kind of modification than is the case with the double-standard type. Sometimes the tie-rods can be removed when it is required to pierce sheets of large area, and thus avoid the necessity of using a bigger size of press.

Capacities of Small Presses.—The small bench or stand machines are capable of exerting 1 to 2 tons pressure, the latter force being capable of blanking a disk in mild steel $1\frac{1}{2}$ inches diameter by $\frac{1}{32}$ inch thick; or $\frac{3}{4}$ inch diameter by $\frac{1}{16}$ inch thick; or 5 inches diameter by ·01 inch thick. The performance of a 6-ton press on similar material is: 7 inches diameter by ·02 inch thick; or 2 inches diameter by $\frac{1}{16}$ inch thick; or $\frac{1}{2}$ inch diameter by ·128 inch thick.

Medium Powers.—The medium range of pressures, from 12 to 20 tons, may be specified, and, for instance, a 12-ton press will blank in mild steel 9 inches diameter by ·02 inch thick, or 3 inches diameter by $\frac{3}{32}$ inch thick; or cut and form a cup in $\frac{1}{32}$-inch thick steel 3 inches diameter by $\frac{1}{2}$ inch deep. A 20-ton press will blank 11 inches diameter in ·025-inch thick sheet, while a similar power when employed for work of large area cuts 24 inches long by 3 inches wide in ·022-inch metal.

Higher Powers.—A 40-ton machine cuts 12 inches diameter through ·048-inch metal, or 2 inches square through $\frac{1}{4}$-inch thick plate. At 60 tons pressure, a disk 13 inches diameter by 15 s.w.g. thick may be blanked. The big double-crank presses possess great power, together with large

bed area ; thus, one of 150 tons pressure cuts a blank 48 inches diameter from a sheet 72 inches square and ·048 inch thick, and another of 200 tons capacity blanks to 60 inches square.

Specification of 10-*ton Press.*—In order to give an idea of the proportions of a small power press, the following particulars of a Taylor & Challen geared model may be cited. The gearing gives a slower motion to the punch than is the case with the ungeared type (which is otherwise similar), hence thicker metal can be blanked, or cups can be extended. It should be understood that the pressure rating refers to that applied near the bottom of the stroke, the pressure being less effective when drawing is done, as the work is spread over a longer period.

Pressure exerted at bottom of stroke	10 tons
Stroke	3 to 4 inches
Strokes per minute (usual)	50
H.P. and revolutions per minute of motor	2 h.p. at 950 r.p.m.
Angle of inclination (maximum)	30°
Diameter of crankshaft journals	[illegible] inches
Diameter of crankpin	2¼ inches
Bed to slide (adjustment up stroke half-way down)	8¼ inches
Adjustment to slide	1½ inches
Width between slides of frame	8¼ inches
Width between extractor horns	9¼ inches
Depth of throat	7 inches
Bed, right to left	23 inches
Bed, front to back	13 inches
Hole through bed	9¼ inches
Width of T-slots	1⅛ inches
Slide base, right to left	5 inches
Slide base, front to back	5⅝ inches
Diameter and depth of recess in slide (standard)	1¼ inches diam. by 2 inches
Floor to bed	34 inches
Floor to crankshaft centre	56 inches
Overall height	69 inches
Net weight (excluding motor)	21 cwt

Specification of 350-*ton Press.*—In contrast to this machine, the data regarding a 350-ton double-crank press may be quoted :

Stroke	18 inches
Strokes per minute	14
H.P. of motor	35
Speed of motor	1,000 r.p.m.
H.P. of motor for slide adjustment	7½
Diameter of crankshaft journals	10 inches
Diameter of crankpins	11 inches
Bed to slide (stroke and adjustment up)	44 inches
Adjustment to slide	3 inches
Width between uprights	66 inches
Area of Bed	
Right to left	66 inches
Front to back	54½ inches
Thickness of bolster	6 inches
Hole in Bed	
Right to left	50 inches
Front to back	34 inches

Area of Slide Base	
Right to left . .	65 inches
Front to back . .	42 inches
Floor Space Overall	
Right to left .	151 inches
Front to back .	116 inches
Height	190 inches
Weight (including motors)	49 tons

Choice of Press.—The selection of a press for a specific purpose depends, as will be evident from some of the notes in this chapter, on the force required, the area of the sheet to be blanked, its thickness, whether a cupping operation is necessary, and if hand or automatic feeding has to be done. Many of the open-fronted presses afford ample capacity as regards area of bed, but may not supply the essential rigidity to work intricate tools which will endure for a long period, and turn out stampings true and interchangeable. The question should be considered, therefore, whether for the more difficult kind of job a double-sided machine is to be preferred. When dealing with thick or tough metal it may be much more economical to use a press of this type.

Hand or Automatic Feeding.—The choice of either of these methods of passing the stock to the dies may in certain instances affect the selection of a press. A large proportion of the objects stamped from strip are thin, consequently the open-fronted, auto-feed press is generally a suitable type to employ. But for a good many drawing operations the double-sided pattern is preferred. Hand feeding is adopted extensively for small lot production, and also for shapes for which it is not convenient to rig up an automatic feed, while, of course, there is a lot of large stuff which can only be supplied by hand to the dies. Some of the secondary processes performed on stampings necessitate hand feeding, unless large numbers warrant the employment of auto-feed mechanism. The inclined position of a press often facilitates hand placing.

Automatic Roll-feeding Systems.—Blanking of large numbers from strip or sheet warrants the use of a semi-automatic or fully automatic feed, and there are several kinds of apparatus which take raw or partially treated units and transport them to the die. Taking a survey of the various methods, that of feed by means of rollers is applied very extensively. It assures safety to the attendant, maximum output, and reduction of scrap to a minimum. In the case of successive or "follow-on" operations the various punches are spaced one, two, three, or more feeds apart, and if exact equality is required, centring is employed or pilot pins may be fitted to locate the strip, such as in the manner seen in Fig. 171, or side punches may be arranged, to leave projections on the strip (Fig. 172), which abut against raised edges on the die, and act as locating stops. The feed rolls give a slight excess motion so as to ensure this stop action. The black outlines indicate the punching at one operation, and the dotted outlines what is performed after feeding forward one pitch.

Roll feeds may be either single or double, the advantage of the latter type being that scrap is reduced to the minimum, as when the leading pair of rolls have fed all they can, the others take control. The features of the mechanism comprise a ratchet or friction feed, gearing to vary the feed ratio, and a relieving device to permit the strip to float when

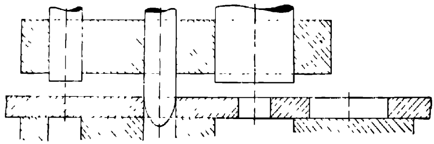


Fig. 171.—Pilot-pin method of centring pierced hole before blanking

accurate location is desired in the way just described. Hand lifting is also necessary for the purpose of inserting the stock. The feed travel varies, in different presses, from a maximum of 1 inch in little machines to a maximum of about 15 inches—this in a press which blanks large disks. Transmission of the motion from the crankshaft is by means of a crank

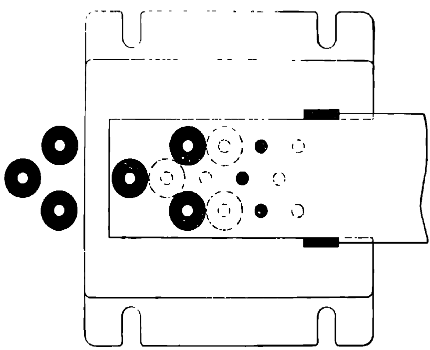


Fig. 172.—Mode of piercing and blanking washers from roll-fed strip.

disk on the end of the crankshaft, thence to a ratchet wheel, friction wheel, or free wheel, the two latter devices permitting of fine adjustment of the crank-disk throw. The ratio of movement from the crankshaft is varied by bevel gears, as 1 to 1, 2 to 1, or 3 to 1. A higher speed can be given to the outgoing rolls, to compensate for the lengthening and sagging of the strip after punching. In one design the roll brackets are pivotally attached to the table, and can be swung out of the way for die-setting, or hand feeding.

Stock Control.—The coil carrier that stores the strip consists of a stand carrying a bracket adjustable for height, and this has a disk with four slots in which rods can be adjusted radially to suit the size of coil, held on by a spider, the hub on which the carrier rotates having ball bearings. A simpler equipment consists of a reel bolted to the end of the feed-roll support, and having flanges adjustable for width apart. A similar reel driven by a chain can be mounted at the opposite end to wind off the scrap (Fig. 173). Another kind of winder has a separate stand, the spindle being chain driven from the feed-roll shaft on the press, and revolving the winding drum frictionally to allow for the increasing diameter of the coil. The drum is grooved so that the coil of scrap may be wired before removal.

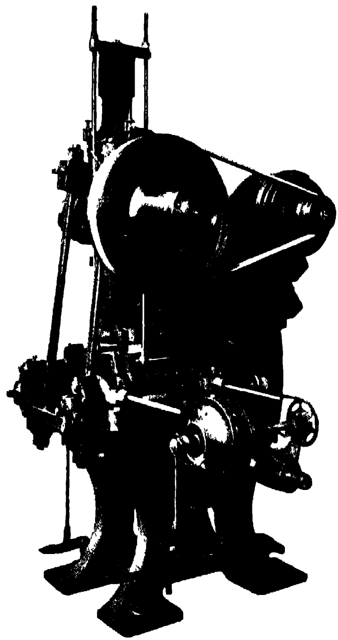


Fig. 173.—Equipment for washer production, double roll feed, and scrap winder (Taylor & Challen, Ltd.)

Straightening Rolls.—To straighten the strip metal a set of rolls is mounted on a separate stand adjustable for height, or it may be bolted to an extension table at the side of the press (Fig. 174). Five rolls effect the straightening, the two top ones being lifted by a lever to enable the strip to be started in. Wide stock is drawn through the straightening rolls by two pairs of feed rolls, with or without feeding-out rolls.

Scrap Cutter.—A good many presses are equipped with a scrap cutter (Fig. 175), which severs the blanked strip and delivers it into a box. When round holes are punched through fairly wide strip the scrap can be sheared through the narrowest sections, and the resulting pieces be used for stamping small articles.

Cutting to Length.—A different reason for cutting after a punching operation is to get pieces to dead lengths. A Taylor & Challen double

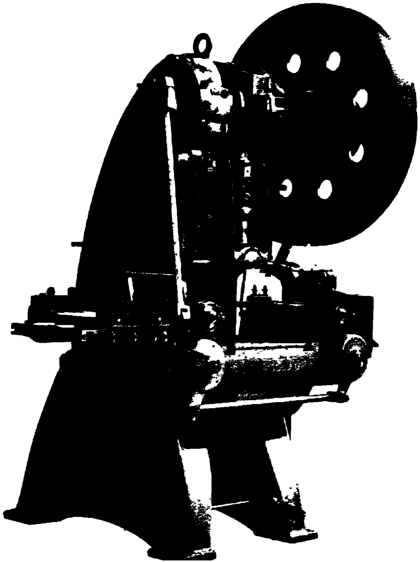


Fig. 174 —Schuler blanking press which has straightening rolls, double roll feed, and scrap cutter

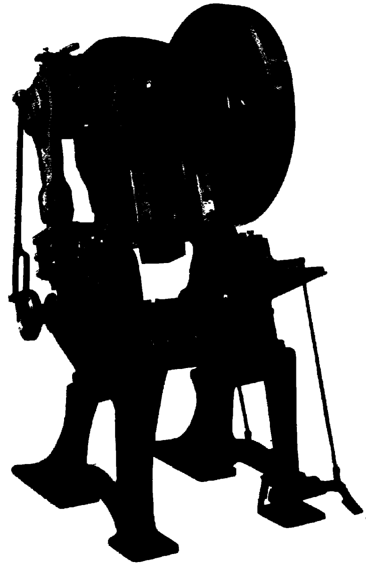


Fig 175 —Double roll feed and a scrap cutter are fitted to this press.

press is built with duplicated frames and one flywheel pulley driving the crankshaft. The strip is fed to a table at the left-hand press, passes through the first pair of feed rolls, and is pierced with a number of small holes. Then it goes through the second pair of rolls to the other press, where cutting-off tools sever it, leaving as many holes in the unit as may be required. The length of strip cut may be varied by substituting different ratchet wheels and so altering the feed length.

Gripper Feed.—This is an accurate mode of propelling the stock against a stop. Two grippers are provided on the inlet side and two on the outlet side for feeding and clamping the material (Fig. 176). When working with pilot pins the holding grippers can be lifted just before the stamping operation takes place.

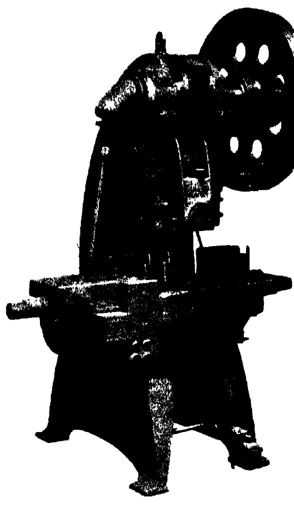


Fig 176.—Gripper feed on a Schuler press

Slide Feed.—Raw material, as well as partly finished articles, are often handled by a slide mechanism. In the simpler forms there is a slide which moves the piece to the dies, and ejects and pushes them off without the operator's hands coming near the dies. The slide is actuated by hand, or mechanically. More elaborate construction is noticeable in feeds for presses which produce blanks, punch apertures, or make large numbers of holes at high speed. An example of the latter class of work occurs on a press that punches square holes along the edge of a strip, 25 inches by 12 inches, which is held by grippers to a feeder rail, and propelled intermittently. The stop motion can be set to leave a space between the openings equal to two, three, or more pitches, and the rate of punching is 120 per minute. A press incorporating slide feed for multiple blanking operates eleven punches, placed in staggered fashion, to leave the least quantity of scrap from the strip. An adjustable stop screw determines the amount of feed, and springs bring the feed slide back to this stop after each stroke. Spring rollers guide and prevent the strip from moving back with the feeder slide. A gripper pivoted to the slide clamps the strip to feed it forward. Fig. 177 shows the application of a slide feed on multiple-die work.

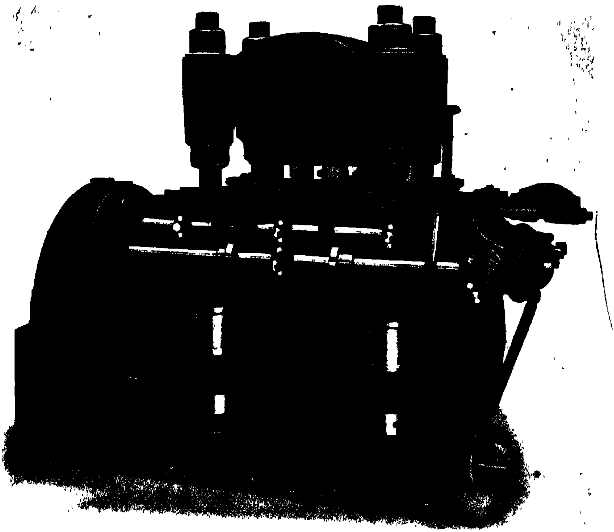


Fig 177 —Slide feed on multiple-die automatic press

Preparation of Scalloped Strips.—The highest rate of blanking is performed on the multiple-die presses, and those which operate a stagger feed under one punch. The sheet or strip is fed by grippers and slides so as to utilise every possible square inch. Two systems are employed for high-rate production, the first that of punching out the blanks in zigzag formation from a whole sheet, and the second that of shearing the sheet into strips with scroll or scalloped edges conforming as closely as possible to the contour of a row of circles (Fig. 178). For this latter service a special scroll-shearing machine is used, combined with a rotary slitter. The

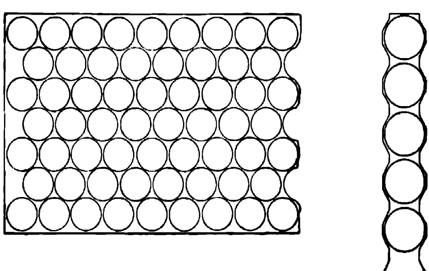


Fig. 178.—Staggered system of blanking, and scalloped strip.

sheet has to be placed against gauges on the table of the slitter, and dogs on two feed bars pick up the sheet and deliver it to the rotary cutters, which trim both sides straight and parallel. It then falls on to the table of the guillotine shear, where the fingers of a set of reciprocating feed bars place it under the specially shaped blades of the shear. Two pairs of scalloped blades are required for cutting single-row strips, so that one strip falls to the rear of the outer blade, and the other in between the blades. One pair of blades is necessary for double-row strips. The stroke of the feed bars is adjusted to be a trifle longer than the width required for a strip, and the sheet is consequently fed past adjustable stop gauges on the table. On the return stroke of the feed bars the sheet will be carried back, then stopped and stripped from the feed fingers by the stop gauges. As these latter are set to the exact width of the strips to be cut, uniformity of all strips is ensured.

Blanking the Strips.—Finally the strips are automatically transferred to the press, leaving the scrap stacked at the shearing machine. The strips lie in stacks on the left-hand front table of the press, from which they are lifted singly by four suction rubber pads, operated by an air pump. The automatic feed apparatus embodies two pushers that thrust the strip rapidly towards the back of the press (the vacuum being broken at the same moment), and under the fingers of the feed bar, which has a reciprocating movement to and from the die. The feed fingers are spaced along the feed bar at intervals corresponding to the pitch of the centres of the blanks to be stamped at each stroke. At each stroke of the feed bar towards the die the last finger on the feed bar, nearest to the left side edge of the strip, pushes it under the die. The feed fingers thus work consecutively, starting with the first finger on the left-hand end of the feed bar. After the last blank has been cut, a kicker throws the scrap into a box. In the event of a strip jamming, an electrical attachment stops the press. This sort of shearing and blanking equipment is made by the Bliss Company.

Stagger Press.—This class of feeding involves supporting the sheet on a large table which is fitted with adjustable apparatus to pitch the distances as required (Fig. 179). The alternative methods are : to use an interchangeable longitudinal dividing bar, and adjustable cross-notches, or adjustable longitudinal and cross-dividing notches. The main purpose of the presses that produce blanks by the scallop or the stagger system is that of producing lids and bottom of cans and boxes of all sorts from tinplate or other thin material, but machines are also built for heavier work. A heavy, geared, automatic stagger press, for instance will blank sheet of 16 s.w.g. to 6 inches diameter ; it will also do drawing.

Dial Feeds.—A turntable supplies a mode of continuous feeding of units without risk to the operator (Figs. 180, 181). It is difficult to differentiate between the uses for blanking and piercing and those for drawing, embossing, necking, lettering, marking, and many other processes, because

in many cases the principle is the same. The dial can be employed in two different ways, either to act as a carrier for placing successive pieces over a die, or to hold a set of dies, which in turn bring the part under the punch.

The partial rotation is effected from a crank disk on the end of the crankshaft, or by mitre gears thereon, thence to a ratchet wheel or friction band on the turntable. Or an escapement movement is utilised with indexing and locking from a vertical shaft. Other methods of locking are adopted, such as cam-actuated transmission from the crankshaft working a stop for the indexing positions.

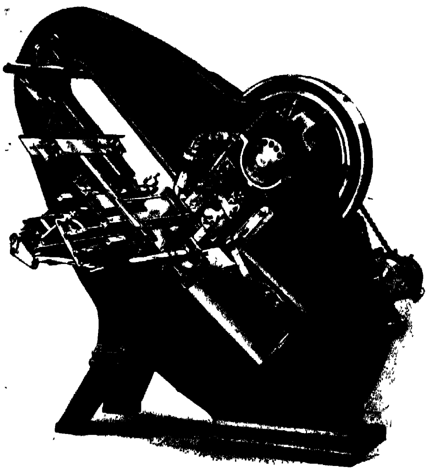


Fig 179 —Rhodes' automatic stagger-feed press for high production

An exception to the usual practice of having stations to the dial may be observed on a press with mixed feed arrangements. The dial has a plain, smooth face, and the components are laid on it, to be swept around intermittently to a cam-operated pusher that feeds them into position over the die.

When objects must be taken over the die, this is accomplished by means of a carrier plate fastened on the dial, the plate having holes or recesses of suitable shape. Another scheme is that of making holes in the dial for the reception of jigs. The number of stations varies according to the diameter of dial, and the size of the work, as many as forty being used for small pieces.

Applications of Dial Feeds.—Among the numerous interesting uses of these feeds, the following may be noted: the simple operation of flattening washers and links, etc., is performed from a turntable holding ten dies on to which the articles are placed. A stationary die directly under the centre of the ram supports the dial against the pressure of the flat-ended tool which gives the pressure, and an automatic wiper then clears the flattened pieces from the dial. For flattening, piercing, and shearing the corners of brass cable clips of long strip shape, the carrier plate has sixteen grooves, into which the clips, with the ends folded

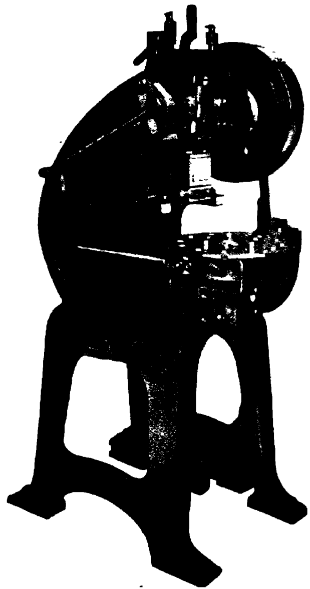


Fig. 180 —Light press equipped with twelve-hole turntable (Taylor & Challen, Ltd)

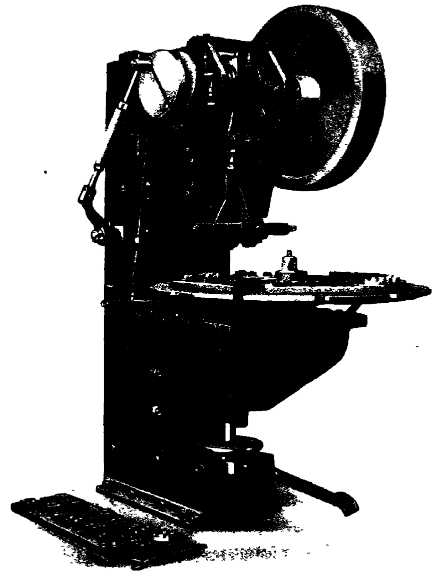


Fig 181.—Dial-feed press of fabricated construction. (Rhodes.)

over, are placed, and gripped by spring-pressure buttons. On the centre line of the press there is a double set of tools, both sets working simultaneously on two clips. One set does the flattening, the other set pierces two holes and shears the corners to 45°. The turntable is relieved from pressure, as the ends of the clips project from it.

Some objects are placed on pegs fixed in the dial, or secured to it by screws and clamps. Cups may be dealt with in this manner, to be flattened, pierced, lettered, or embossed. In certain cases the die is located in the press ram, and the circle of punches on the turntable; after dropping a cup on a punch it comes under the die and is necked, then an extractor pushes it out of the die and lets it fall loosely on to the punch, from which the attendant can later remove it.

Perforating Feeds.—An intermittent motion indexes lamp galleries, air-regulator thimbles, lamp-wick carriers, strainers, and various kinds of tubes for the piercing of sets of holes, round, square, oblong, or contoured. Sometimes the support on which the part is mounted revolves, but where, for example, small thimbles are pierced, these are rotated intermittently upon a stationary support through the medium of gears. Clamping by a pallet pressing the piece tightly upon a formed mandrel on the spindle which does the indexing is observable in the production of a lamp gallery. Part of the operation consists in blanking out portions to leave the prongs at the top, and another setting pierces air holes in the lower part. For parallel tubes a long bolster is attached to the press bed, and has at the right-hand end a round horn on which the die is mounted. Opposed to the horn is a pallet plate on a spindle thrust along by a lever motion, and the tube becomes gripped between the pallet plate and a flange on the horn, both plate and flange turning on ball bearings. Ratchet feed from the crankshaft revolves the pallet plate spindle.

Tube Feed.—Small articles sometimes lend themselves to feeding by tube or magazine, in which they are placed by hand, or fall from a hopper. Transference to the dies takes place by slide, and there may be a spring gripper included which holds the blank until the time comes for it to be transferred, thus preventing false movements. Hopper and tube feeding occurs in a press for flanging and piercing small cups. They are dumped into the hopper, from which they are fed by pegs down a vertical tube, from the bottom of which a slide moves them to the die. The press stops automatically should a cup happen to get upside down. A combination of a tube supply with gripper feed affords an alternative for pieces to be pierced, embossed, or otherwise pressed. The tube, inclined or vertical, drops the parts where the hinged gripper fingers take hold and effect the transference to the die. On the return stroke the fingers open to miss the piece just fed (Fig. 182), and at the end of the travel take hold of the next blank. When the time comes to pass this to the die it pushes off the unit just pressed.

Magazine Feed.—Some of the horizontal presses have a magazine type of feed down which the work slides or rolls into position. A composite

arrangement on a vertical press has a magazine from which the parts go to a push feed. As the stroke of the ram in this machine happens to be short the speed of the push feed has to be accelerated, which is done by using elliptic gears for the connection from the crankshaft.

Die Slides.—A practice sometimes followed for both small and large presses is to put the die upon a slide, drawn out to emplace the work, thus avoiding danger to the operator. In some cases there is not much room for the attendant to reach to the die, and this is another reason for utilising the slide. A little bench press thus fitted has the slide moving between shouldered gib strips, and reciprocated by cam and lever from the crankshaft. A similar mode of moving the slide is adopted in some large presses. In another example, a pneumatic cylinder retracts and returns the die slide to a stop, the air valve being hand controlled independently of the ram strokes. Handwheel and racking gear furnishes yet another way of moving the slide, and a safety stop bolt is provided so that the treadle which starts the press cannot be moved until the die slide has been locked in the correct position.

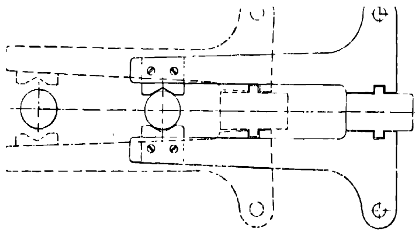


Fig. 182.—Feed fingers which receive piece from a feed tube, and transfer it to the die

Hot Brass Pressing.—A branch of press work which has developed extensively, and is comparable with blanking, is the stamping of all sorts of shapes in hot brass, to avoid machining, or reduce this to a minimum. The alloy is consolidated by the process, wastage in scrap is largely reduced, and sizing is uniform, powerful double-sided presses being employed (Fig. 183). A great many forms require the use of split dies, which have to be opened for the removal of the pressing. The tools necessary include a vice and side slides, and sometimes a bottom slide. The split dies are opened by these means. The motion to the vice is toggle actuated, worked by a cam on the crankshaft, through links and levers, the side slides moving transversely in conjunction with the main slide. As the press ram descends, these enter each side of the die space, thus forming cores over which the pressed articles are extruded. The bottom motion is worked by links and levers from a crankpin on the end of the crankshaft to an eccentric shaft that operates a connecting rod and slide moving vertically. A punch can be fixed in this slide, and as the main slide descends the bottom motion slide ascends and enters the die space, so forming a core over which the pressing is extruded (Fig. 184). The vice may be opened and closed by hand to hold the hot blank in place until the

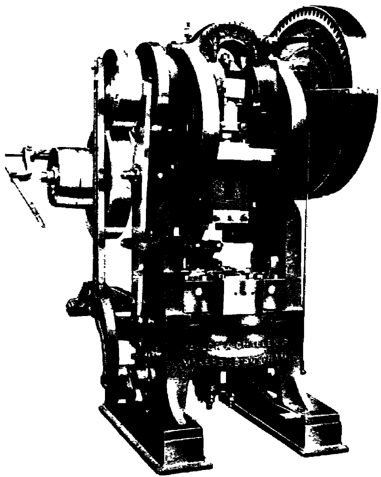


Fig 183.—Press for hot brass work, all the movements being automatic

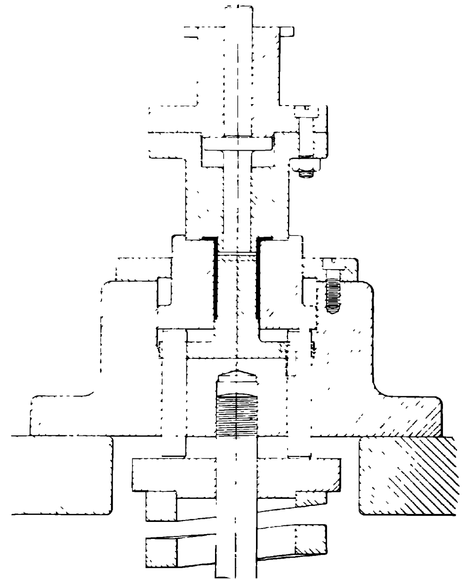


Fig 184.—Die used for hot brass work. (Taylor & Challen, Ltd.)

press is started, and the power closing takes effect. A spring-controlled collar keeps up strong contact with the top die whilst the pressing is being done, and prevents escape of flash. Extractors are necessary to eject the piece.

The dies have to be kept hot all the time in order that the brass shall not be cooled by coming into contact with them; for this purpose a ring gas-burner surrounds them, and this is always kept going. At first a substantial slab of hot iron is placed on the lower die, and the upper one brought down to touch it. The billet to be pressed has to be heated before insertion, to fairly near the melting-point. Presses for this class of work are of about 100 tons power.

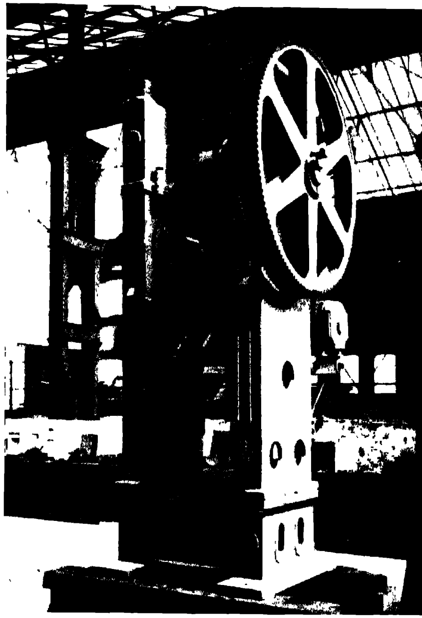


Fig. 185.—Built-up press which has motor and electro-pneumatic clutch drive. (Cowlishaw, Walker & Co., Ltd., Stoke-on-Trent.)

The steel from which the dies are usually made contains from 2 to 2·5 per cent. carbon and 10 to 12 per cent. chromium. It is oil-quenched from 1800 degs. F. and tempered to 600 deg. F., and has a Schleroscope hardness of 85 to 95.

Some of the data concerning the press illustrated in Fig. 183 are:

Pressure exerted at bottom of stroke	100 tons
Stroke of punch .	8 inches
Stroke of vice slide	3 inches
Stroke of side slides	2 inches
Stroke of bottom motion slide	3 inches
Strokes per minute, usual	60
Adjustment to slide .	3½ inches
Width between sides of frame	24 inches
Slide base, right to left	22½ inches
Slide base, front to back	10½ inches
Space in dies, when vice is closed	6 × 6 × 6 inches
Power required .	10 h.p.

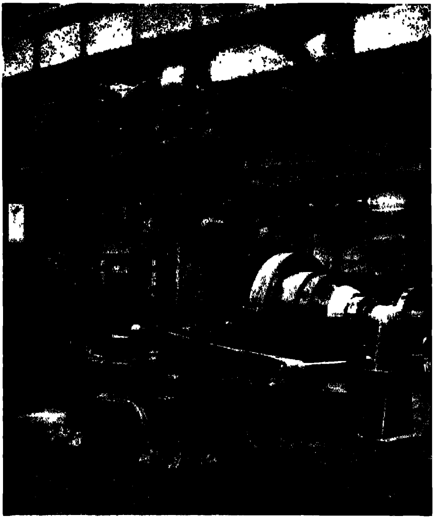


Fig. 186.—300-ton blanking press, double geared and driven by multi-plate external friction clutch (Hordern, Mason & Edwards, Ltd.)

Systems of Driving Presses.—Finally, consideration may be made of the different ways of supplying the driving power, more variety being noticeable in this respect of late years. The motor drives have largely supplanted belt transmission from a line shaft, and a further development has been that of replacing flat belts from motor to crankshaft pulley by rubberised multiple vee-belts. Very short centres are thus possible, and many of the motor mountings are close to the crankshaft, such as high up on the back of the press. A hinged tensioning arrangement enables the motor to be set farther away if necessary. A good many presses carry the motor at the side, on a facing of the standard, or on a horizontal bracket, and on the large double-standard machines a convenient location is at the top of the cross-girder. Another system is by chain drive from the motor to a first-motion shaft and thence by pinion to the gear on the crankshaft, while double-reduction drive entirely by gears is also employed. Fig. 185 affords a good example of electric driving, with V-rope from

Fig. 187.—A Tecalemit hydraulically-operated work-loading table, the height of which is adjustable to suit that of the press tools.

the motor to the flywheel. The electro-pneumatic clutch is controlled by a rotary timing disk driven by the crankshaft. Push buttons control the operation of the press, these being located in a convenient position at the front. Fig. 186 gives an idea of a pulley-and-clutch drive on a press for heavy blanking. A motor may be substituted—20 h.p. is required to drive the press.

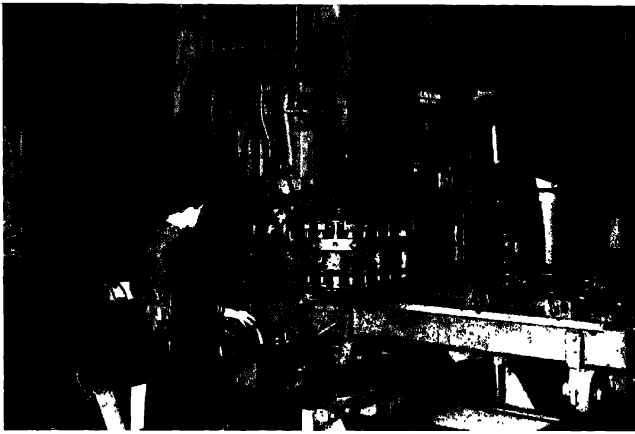


Fig. 188 A Wiedeman R 7 turret press installed at the Witton G.E.C. factory It carries up to 32 blanking tools, and is suitable for sheets measuring up to 5 ft by 10 ft (G E C.Ltd)

The conditions of press driving demand a motor possessing the highest possible overload capacity for a short period, with maximum speed reduction. There is a difference in the energy requirements in blanking and drawing. Blanking is completed in a very brief portion of the press stroke, and the flywheel supplies nearly all the energy required to send the punch through the metal. The motor then takes the rest of the cycle to bring the flywheel back to full speed and energy. But in drawing operations the work is more prolonged and the motor has to sustain a considerable overload.

CHAPTER 10

DRAWING PRESSES

THE term "drawing press" is rather elastic, because a considerable amount of drawing is done on blanking presses, but specifically it refers to a type of press which has double action, a central ram moving the punch, and an outer slide forcing down the blank-holder which grips the blank with sufficient friction to enable drawing to be performed without tearing the material or allowing it to wrinkle unduly. It is possible, however, to employ a single-action press for deep drawing by fitting a device to the table which supplies this pressure automatically, and some of the extending presses are of this single-action type. The action in drawing differs from that of blanking, where the greatest pressure is concentrated for a very short time as the metal is sheared, whereas in drawing the pressure must be sustained. Even more severe work is entailed when an ironing process takes place, *i.e.* when the object is drawn and also compressed in order to obtain a finish, or produce uniformity of thickness, or make tapered walls. These essential differences affect the designs of some of the presses as regards strength of the parts, driving power, and length of stroke. Shallow drawing does not involve any difference in the last-named respect, but deep-drawing types may employ a stroke as long as 30 inches.

Combined Blanking and Drawing.—Shallow articles can be made with combination tools on blanking presses of ordinary or multiple-die types, and on drawing presses proper, the same principle being often adopted. Alternatively, the blanks can be stamped separately, and transferred to the drawing press. Another procedure consists of blanking and drawing in one operation, followed by one or more stages in redrawing, the work being distributed between two or more presses, depending upon the plant available, or the numbers required. Extending or reducing is an operation sometimes performed without the use of a blank-holder, one of the chief applications of this process being for making cartridge shell cases, where the wall has to be thinner than the bottom, the punch pushing the partially drawn piece through the die, the press being of the simple vertical or horizontal long-stroke type.

The fact that the single-action press can be used for a wide range of work, including blanking, accounts much for its popularity. This is especially the case when moderate numbers of pieces are required, because it can then also be used for blanking, piercing, bending, and other operations. With the aid of a die-cushion or a drawing device it is possible to

convert a single-acting press into a drawing press, and owing to the nature of the mechanism a short stroke can produce a deeper stamping. The added complication in the driving mechanism of the double-acting press tends to make it slower in working than is the case with the simpler single-action design.

Blank-holding Pressure.—The amount of pressure required to hold a blank depends upon several factors. The primary object is that of preventing wrinkling, but the resulting elongation of the article has also to be considered, as well as the quality and state of the metal, its thickness, the shape of the part, and depth of draw. A blank will only withstand a

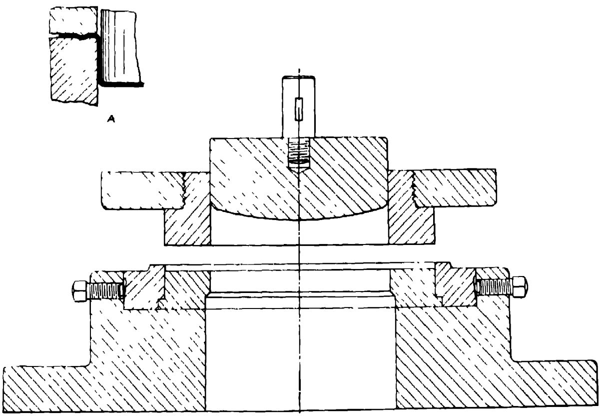


Fig 189.—Combination die for blanking and drawing A, Beading, to increase the holding power of a blank-holder

certain amount of elongation at each draw, and therefore the blank-holder pressure should be as low as practicable consistent with securing freedom from wrinkling. If the pressure is needlessly excessive the sheet will tear, or extra annealing will be necessary between the various stages. The relationship of blank-holding pressure to drawing pressure varies considerably, according to the shape of the work. A very shallow form will not require much drawing pressure, but for deep drawing the holding power will be considerably greater. One method of increasing the holding power for a given press is to bead the blank-holder next to the inner edges (Fig. 189), so that the sheet is held more effectively during the operation. The use of a lubricant materially affects the success of a drawing operation, facilitating the flow of the metal and enabling the action to be carried on with the minimum of wrinkling and elongation.

Principal Types of Drawing Presses.—The usual design for double-action drawing presses employs cams, toggles, or hydraulic mechanism, the last-mentioned method having increased in popularity during recent years. The essential difference between cam and toggle operation lies in the manner in which the holding pressure is taken; in the one the crankshaft has to carry the forming and the holding load, in the other the latter load is received by the frame. Therefore for heavy duty the toggle press should be selected. Furthermore, the wear on the cams has to be considered when heavy pressures are consistently required. Actually, models are built in each type.

Cutting-and-drawing Presses.—The smaller sizes, up to about 5 inches depth of draw capacity, are freely employed for blanking and drawing, using hand or roll feeds. The combined cutting punch and pressure plate descends with the outer slide and shears the blank, which is then drawn through the die by the punch (Fig. 189). One small press for this class of working has the following specification:

Stroke, outer slide	$\frac{3}{4}$ inch
Stroke, punch	$1\frac{1}{2}$ inches
Strokes per minute, usual	250
Feed of strip, maximum	$\frac{7}{8}$ inch
Width of strip, maximum	2 inches
Bed to outer slide, adjustment up, stroke up	6 inches
Bed to inner slide, adjustment up, stroke up	8 inches
Adjustment to outer slide	$\frac{1}{2}$ inch
Adjustment to inner slide	1 inch
Width between sides of frame	$7\frac{1}{2}$ inches
Depth of throat	$3\frac{1}{2}$ inches
Bed. Right to left	13 inches
Front to back	7 inches
Hole through bed	3 inches
Power required	$\frac{1}{2}$ h p
Overall height	65 inches
Net weight	$5\frac{1}{2}$ cwt.

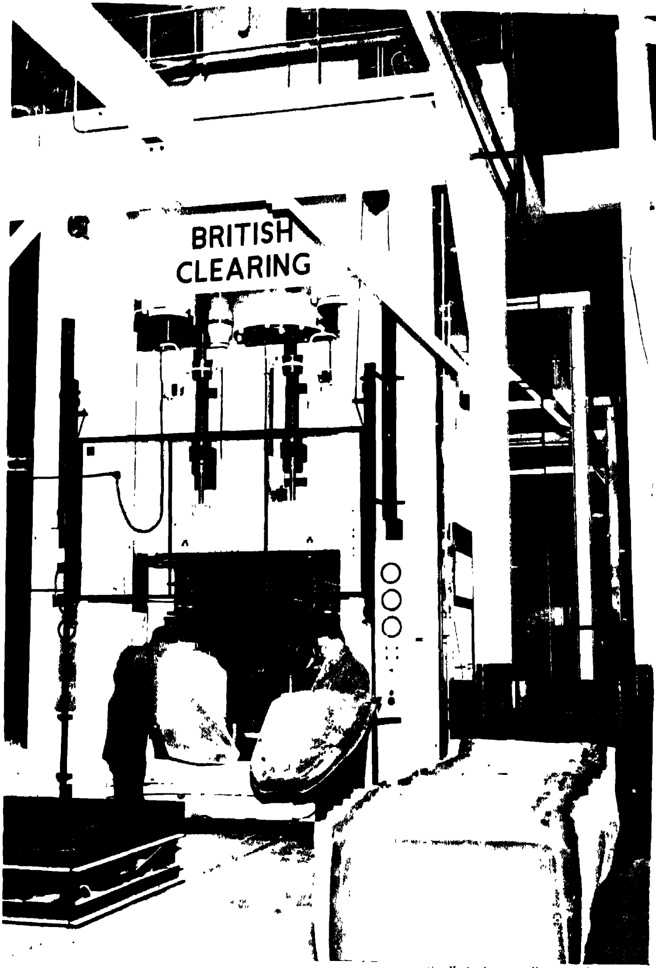
One series of presses made by Taylor & Challen, acting on the same principle, have drawing depths of $\frac{3}{4}$ inch, $1\frac{5}{8}$ inches, $2\frac{3}{4}$ inches, 4 inches, and 5 inches respectively.

The movement of the cams is transmitted to the outer slide by a pair of loops, fitted with rollers in the top and bottom ends, the rollers running in oil-baths. The equivalent of this construction in some presses is to carry up four rods and attach a cross-head at the top for the rollers there. The rods may be prolonged upwards to slide through guide brackets. In all the heavier kinds of presses, however, the general practice is to have rollers only at the top of the slide and fit a spring balance arrangement consisting of four springs anchored to the slide at front and rear, and to brackets on top of the cross-beam (Figs. 190 and 191).

Light presses are direct driven by the flywheel on the crankshaft, and the heavier types by gearing. Double-reduction gears are provided in the larger models in order to give a comparatively slow motion to the

Metal Propellers, Ltd.

A PRESS DEPARTMENT EQUIPPED FOR MAKING HOLLOW-WARE



(Sir W. G. Armstrong Whitworth Aircraft, Ltd.)

MODERN HYDRAULIC "CLEARING" PRESS

Forming large automobile panels in a modern hydraulic "Clearing" press

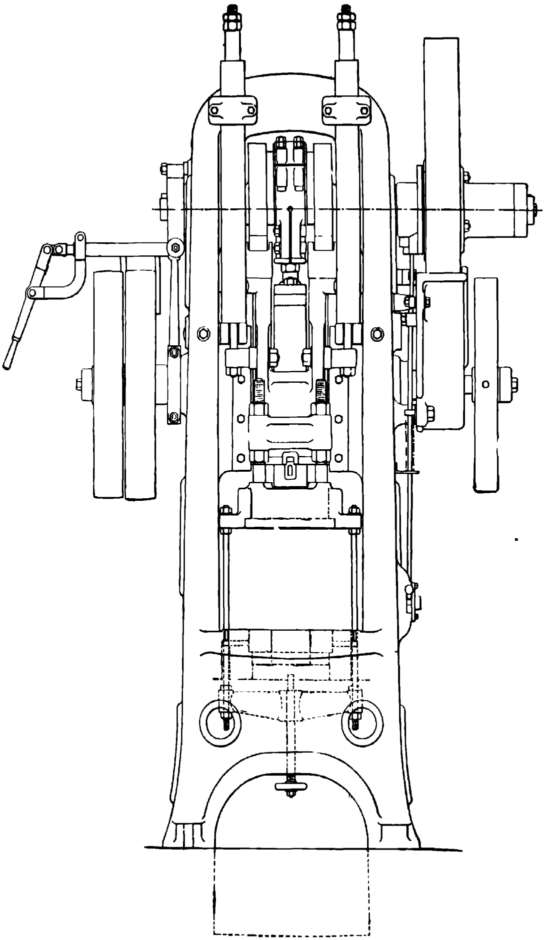


Fig. 190.—Double-action cam-operated drawing press. (Hordern, Mason & Edwards, Ltd , Birmingham.)

punch, and less shock to the metal undergoing treatment. A few particulars of a Taylor & Challen machine of this description are given below:

Deepest draw	5 inches
Stroke: Outer slide	5¼ inches
Punch	10 inches
Largest blank admitted	14 inches diameter
Largest punch admitted	10 inches diameter
Strokes per minute, usual	16
Bed to pressure plate, adjustment up, stroke up	12 inches
Bed to punch-holder, adjustment up, stroke up	16 inches
Adjustment to pressure plate	2 inches
Adjustment to punch-holder	4 inches
Motor	8 h.p. at 985 r.p.m.

This press will draw 10 inches diameter by 2½ inches deep from a blank 14 inches diameter, or 5½ inches diameter by 5 inches deep from a blank 12 inches diameter.

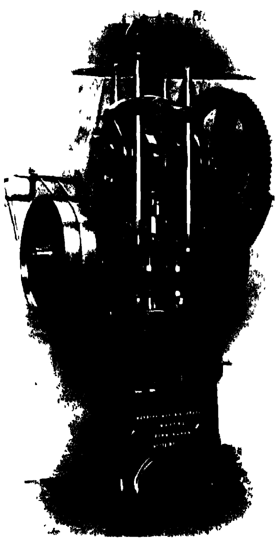


Fig 191—A similar press to that shown in Fig. 30

The disposition of a positive bottom extractor is seen in Fig. 190, this being worked from the rods screwed to the blank-holder. Alternatively, a spring extractor is furnished in some of the light machines.

Toggle Presses.—In these the crankshaft has only to take the drawing pressure, but not the blank-holding pressure, because of the connection of the toggle links to the frame, against which they thrust. The system is employed with success for drawing pressures of 400 tons or more. Pressure is maintained during 90° angular movement of the crankshaft. The main variations in the constructional features may now be considered.

Frames.—The differences in regard to these depend upon the height necessary, the width, and whether a single- or double-crank drive is used. A small press may measure 2 feet between the sides, whilst one of the largest measures 18 feet and requires a 125-h.p. drive.

Castings are generally used for moderate sizes, but fabrication is adopted for some of these, as well as for large machines. The bed, standards, and top girder are keyed and bolted together, " shrunk " tie-rods being fitted to take the stresses. An auxiliary bedplate may be provided on an otherwise standard press in order to give increased height for deep-drawing tools. As an example, the regular (maximum) height from pressure plate to bed, 43½ inches, could be increased to 54 inches by fitting a low-level bed.

Balancing.—The mass of the slide is counter-balanced with four springs in medium-sized presses and by weights in other cases, the latter being located at the top of the frame (Fig. 192). The alternative is to bolt weights to the arms of the gears on each end of the crankshaft. Buffers are also fitted to the toggle arms in many presses.

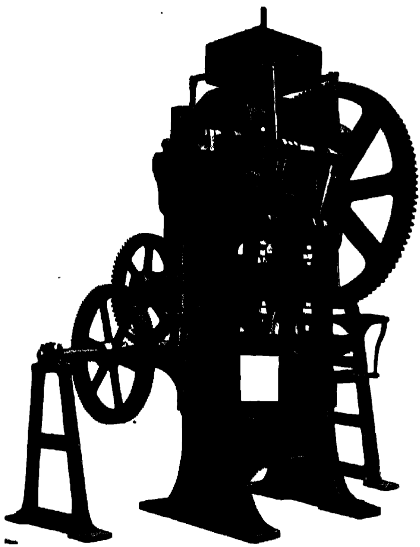


Fig 192 —Toggle drawing press having balanced slide (Lee & Crabtree, Ltd)

Slide Adjustment.—The adjustment of the blank-holder by ordinary nuts and bolts gives place to hand-wheel and worm-gear mechanism in big presses, a motor sometimes actuating the punch adjustment.

Pneumatic Blank-holder.—This is a special fitting found on the Schuler presses and is intended to enable the pressure to be ascertained with accuracy, and maintained so as to give the best results. A ring-shaped holder has a spherical bearing surface, and the air pressure within is regulated until it is found that a blank is drawn without wrinkling. Once the pressure has been determined its absolute value is stamped on the tool, and no further experiments are necessary for the next occasion. As the piston is free to float, it adapts itself to the sheet, or to any irregularity in the press action caused by wear. In addition, the fitting time for tools is considerably shortened, because

adjustment of the blank-holder pressure is effected merely by altering the air clamping.

Methods of Driving.—The method of driving a drawing press depends on its type and size, the direct drive being suitable for the small machines, whilst single gearing, double gearing, and treble gearing are employed for the bigger machines. The most powerful types, which have twin drive for the crankshaft, have the gears at each end so as to avoid any risk of twisting. In order to leave the floor space clear, some makers prefer to put the motor on a bracket at the side or top of the framing.

Clutches.—The sliding or rolling key clutch widely employed on blanking presses has a more limited use as regards drawing presses. Some of the latter, in the smaller sizes, employ these clutches, but for proper control of long strokes a friction clutch is generally used. An automatic key clutch of the cam style is fitted to Taylor & Challen drawing presses, the shape of the key being similar to that of the clutch illustrated in Fig. 160 on p. 142. On some of the toggle presses a gripper friction clutch is used, comprising pairs of pivoted pincer-like grippers that seize a rim on a clutch disk attached to the first-motion pinion. A driver, carrying the grippers, rotates with the driving shaft, and a revolving sliding cone operates the grippers.

The starting lever has to be pulled off a projection on a vertical rod connected to the crankshaft, thus enabling the sliding cone to be moved, causing its taper surfaces to expand the gripper ends and start the drive. As the crankshaft revolves, the vertical rod descends far enough to allow the projection on it to come under the starting lever, and when the slide has nearly reached the top point of its stroke again this rod rises quickly, carrying the starting lever with it and throwing out the clutch, a brake-band being tightened around the clutch disk at the same moment. An emergency lever is also placed in a convenient position, enabling the press to be stopped instantaneously.

A similar mode of control is utilised for this firm's multiple-plate friction clutch installed on all the more powerful presses. This has a series of inside and outside clutch plates running in an oil-bath and engaged by the action of toggle levers controlled by a sliding ring. The friction clutch provides a smooth and shockless engagement, and perfect control at any part of the stroke.

The construction of the multiple-disk clutch fitted to Rhodes' presses is seen in Fig. 193. It is built into the flywheel, which has grooves for vee-ropes, and rotates on roller bearings.

Capacities of Toggle Presses.—A comparison of the capacities and principal dimensions of small and large presses by Taylor & Challen may now be given. In the first case the drive is by a double gearing on to the crankshaft; in the other, treble gears are employed with twin gears on the crankshaft.

SMALL TOGGLE PRESS

Deepest draw	7½ inches
Largest blank admitted	18 inches diameter
Largest punch admitted	12 inches diameter
Stroke: Outer slide	7½ inches
Punch	15 inches
Strokes per minute, usual	10
Width between sides of frame	24 inches
Bed to pressure plate, adjustment up, stroke up	21 inches
Bed to punch-holder, adjustment up, stroke up	28½ inches
Adjustment to pressure plate	3¼ inches
Adjustment to punch-holder	2¼ inches
Bed, front to back	26 inches
Power required	5 h p.

LARGE TOGGLE PRESS

Deepest draw	18 inches
Largest blank admitted	54 inches diameter
Largest punch admitted	35 inches diameter
Stroke: Outer slide	18½ inches
Punch	36 inches
Strokes per minute, usual	3½
Width between sides of frame	56 inches
Bed to pressure plate, adjustment up, stroke up	43½ inches
Bed to punch-holder, adjustment up, stroke up	52¾ inches
Adjustment to pressure plate	4 inches
Adjustment to punch-holder	6 inches
Bed, front to back	68 inches
Power required	75 h.p.
Net weight	980 cwt.

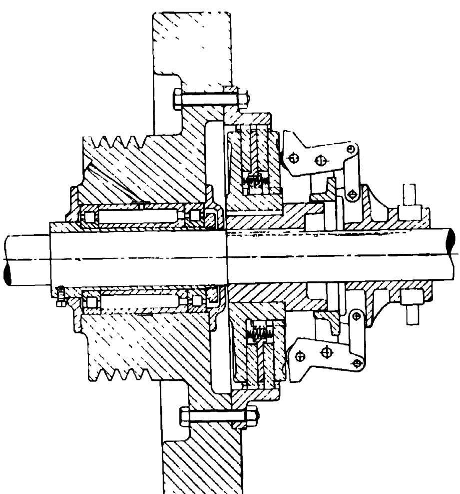


Fig. 193.—Rhodes' multiple-disk clutch

One of the largest Bliss presses has a bed area of 65 × 218 inches, takes 125 h.p. to drive, and has a 20-h.p. motor for the adjustment of the inner slide. The crankshaft is 16 inches diameter at the journals, and 17 inches at the crankpins. The gears at each end of the crankshaft are 12 feet diameter. The framing of this machine is built-up, with keyed joints and four tie rods shrunk in position.

Rising-table Toggle Press.—A different method of working is to be noticed in a press which has the usual crankshaft action for the punch-holder, but carries a fixed blank-holder, adjusted by threaded bolts to the position required. The holding pressure is supplied by the table, which is raised by toggle levers actuated from rods reaching from the crankshaft ends down the outside of the frame. This arrangement gives greater tool space, and end play in the toggle mechanism is absorbed automatically by the weight of the table and die. An ejector placed under the table extracts the pressing as the table descends. The punch has a stroke of $14\frac{3}{4}$ inches, but if the blank-holder is removed to convert the press to single action, the combined movement of table and slide gives the exceptionally long stroke of $23\frac{3}{4}$ inches.

It may be mentioned that the inverted principle has long been employed for certain kinds of drawing, notably that of hollow ware, for which a long stroke but low holding pressure is required. The presses made for this duty carry a stationary blank-holder, and the table is raised by cams, while the punch descends. Free access is given to the table by placing the driving gears beneath the floor.

Single-action Drawing Presses.—For those classes of work not needing a blank-holder, a good many kinds of single-action presses, of both long and short stroke, are available, fed either by hand or by pusher, dial, or some other mechanical system. The double-sided frame is mostly used, although some of the lighter work is drawn on open-front machines. The points which differentiate many of the drawing presses are the long stroke, necessary for much drawing and extending, and great power so as to maintain the load which occurs for a good portion of the stroke. An exception to the usual cycle of stopping at the top of the stroke occurs in cases where a dwell is required at the bottom of the movement, the brake arrangement being modified accordingly. This difference is necessary when moulding plastic substances, vulcanite, pulp, and various other compositions. Long draws, naturally, necessitate the use of tall presses. Although in some cases it becomes necessary to employ a long-stroke machine for short jobs, it is obvious that a deep draw always requires a long stroke.

Typical Presses.—Some of the small double-sided models give a pressure of 20 tons at the bottom of the stroke and require 1 h.p. to drive. The stroke is 6 inches with an adjustment of 2 inches, ample height being provided for deep drawing, the distance from the bed to the punch-holder being $20\frac{1}{2}$ inches. In one 40-ton press the stroke is variable from

8 to 10 inches. The details of one double-geared machine developing 100 tons pressure are as follows:

Stroke	16 inches
Strokes per minute, usual	8½
Adjustment to slide . .	2 inches
Width between sides of frame	24 inches
Motor . .	10 h.p.

The twin-gear method of rotating the crankshaft is employed on many of the heavy presses, and the tie-bar form of building up is frequently adopted. A special way of carrying the crankshaft is to be seen in a Taylor & Challen 2,000-ton press, the shaft having turned webs adjacent to the connecting rod, these being supported by large cylindrical bearings cast with the frame and fitted with gunmetal liners. The shaft is thus enabled to transmit the heaviest pressures without any tendency to distort. The frame and chief working parts are of steel. The following particulars of this big machine may be noted:

Stroke	24 inches
Adjustment to slide .	⅞ inch
Strokes per minute, usual	3
Width between sides of frame	72 inches
Bed to slide, adjustment up, stroke half way down	49¼ inches
Bed, front to back	72 inches
Hole through bed . .	37 inches
Diameter of crankshaft journals . .	18 inches
Diameter of crankpin	25½ inches
Overall height . . .	275 inches
Motor	100 h.p. at 530 r.p.m.
Net weight	116 tons

Horizontal Presses.—For some specialised purposes drawing or extending presses lie horizontally, one of the principal applications being for cartridge cases. A direct or a geared drive is employed, and the cases are fed down an inclined chute, the punch taking each and extending them to the correct length, after which the extractor gear ejects the case. The speed of working is about one per second, and lengths of stroke range from about 5 to 9 inches in different machines.

Hydraulic Presses.—These are made to large dimensions on the double-action principle. One system is that of placing the drawing die on the cross-head, and running the blank-holder and the drawing slide on two pistons working inside each other in a common cylinder. Another is to have the blank-holder and the drawing slide mounted vertically, as in the toggle presses, the drawing slide being moved by means of a ram in the middle and the blank-holder slide by two rams in the smaller sizes, and four in larger ones. An example of this type gives a drawing pressure of 400 tons, and blank-holder pressure of 320 tons. The relative pressures can be controlled separately. The equipment consists of a low-pressure and a high-pressure accumulator, a high-pressure pump, and high-pressure

compressor, and the necessary regulators and controls. The accumulator supply enables the speed to be slow or fast according to the demands of the object, or the drawing properties of the metal.

A modified type of press, which is comparatively low in cost, deals with large curved parts, such as panels. The scheme consists in stretching the sheet over a form (which may be of wood) mounted on a table, and setting down grippers at each side, the grippers remaining stationary while the form rises with the table by hydraulic ram action. A counter-pressure device on an overhead cross-head may be applied to form impressions in opposition to the drawing motion (see Chapter 2, Vol. III—The Aircraft Industry).

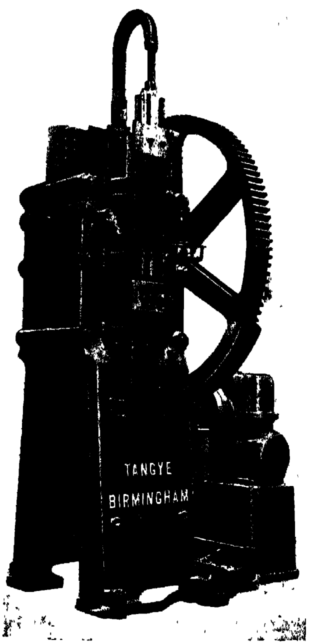


Fig 194—Long-stroke twin-rack drawing press for shell cases.

Screw Presses.—In contrast to the high-speed friction screw presses which deliver a sharp blow, a limited number of drawing presses are used giving a long, slow, drawing stroke by means of a screw; both open-fronted and double-sided types being so built. A maximum pressure of about 170 tons is attained in the largest sizes, with a stroke up to about 2 feet. The drive is by open and crossed belts and a friction clutch, with automatic reverse. When a separate motor is employed, the load on it is reduced by providing the machine with a flywheel drive.

Duplex horizontal screw presses carry punches at each end of the screw, and the dies are held in cross-heads tied by powerful bolts. A screw of 7-inch diameter gives a rate of travel of 75 inches per minute and a stroke of 30 or 45 inches. Open-and-crossed belts on the pulleys transmitting to the gears effect automatic reverse.

Rack Presses.—Another way of obtaining a long draw is through the medium of a rack, machines being constructed thus chiefly for drawing shell cases. The Tangye press has two racks, and while one is descending and drawing the case the other is lifting ready for the next draw. A Ward-Leonard drive is installed (Fig. 194), and the series of standard sizes rate as follows:

Maximum stroke	inches	24	30	33	48	60	84
Maximum diameter drawn	,,	3	4	4	6	6	8
Maximum length drawn	,,	10½	14	16	21	27	39
Speed of drawing	feet per min.	10–30	10–30	10–30	4–24	4–20	4–16

Cold Extruding.—An interesting process of drawing tubular shapes from soft metal is by extrusion, suitable for making shells, cases, and tubes in tin, lead, and aluminium. Rapidly applied pressure causes the metal to flow out of the die (Fig. 195) up around the punch, from which it is then stripped. The heat developed by the blow assists the flow, the length of the piece produced from a given punch depending on the area of the blank. When producing tubes from the more delicate metals such as lead and tin, the work must be carried on at a lower speed than for metals such as aluminium. Presses for extruding this latter material usually operate at speeds in the regions of eighty strokes per minute. One particular make of horizontal press is arranged to be fully automatic, the blanks being fed to the die automatically, and finally removed by a conveyor band. Vertical presses are usually fed by hand or from a magazine, in the former case the punch-holder swinging in and out automatically, the work being stripped from it by hand, and a blank then placed in the die. For reasons of safety, duplex starting levers are fitted, so that the machine cannot be run unless both hands are on the levers. The output on a fully automatic type will reach 4,000 pieces per hour.

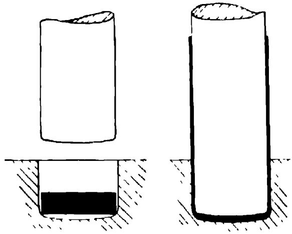


Fig 195 —Cold-extruding method for soft metals.

Compressing Methods.—An interesting phase of press work is that of compression, a type of drawing or reducing in which the shell is necked, or formed into globular shape by dies, either at one operation, or in two or three dies. Materials are also compressed by punches into convenient form for use, or to act as charges of definite size to go in sheet-metal containers. In one instance, fabric is squeezed into a small cylindrical piece by the punch descending on the material as it lies in the die, an ejector then pushing it out, a dial feed being used to move the dies into position. In another case, a hopper feeds powdered material, the attendant depositing a measured charge in the hopper, and this moves forward, loading the die. As the hopper returns, the punch comes down and compresses the powder into a pellet, after which it is ejected and swept away by the next stroke of the press. A safety shield is hung in such a manner that if the hand attempts to follow the hopper the shield moves and stops the press.

Feeding Methods.—Placing of the blank on the die must be effected by hand in a great many instances, but whenever possible this practice

must be avoided. The roll feeds in the cutting-and-drawing presses supply a means of automatic working, but when units have to be fed, the choice may be either that of a sliding or swinging table, feed fingers, or a turntable. The sliding-table device enables the operator to place the blank upon it, and it is then taken forward over the die, removal after drawing being performed by an air blast. A device for locating large blanks is attached to the blank-holder, and consists of guide strips extending out from it. The blank, being laid on these, can be pushed in by hand with the assistance of a slide piece, thus accurately locating it in relation to the die, ready for pressing. This arrangement allows blanks to be positioned on the slide while the previous blank is being drawn.

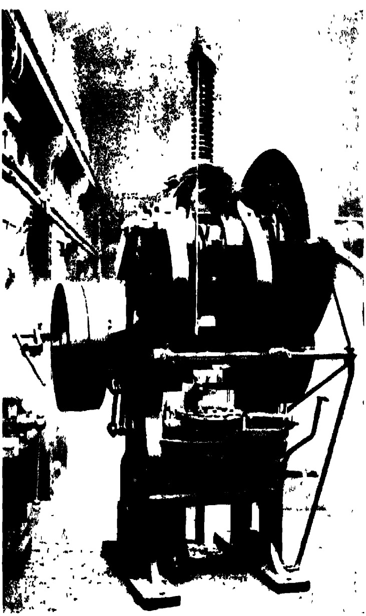


Fig. 196.—100-ton drawing press fitted with turntable.

A combination of a safety guard with automatic feed fingers supplies one method of passing cups to the die for a second drawing. The attendant places a cup on a smooth plate, and as the ram begins to descend the fingers seize the cup and place it in position on the die, at the same time ejecting the previous pressing. At the return stroke the fingers open and release the part. The type of safety guard employed permits a clear view of the operation at all stages.

Turntable Feed.—This serves for a great many redrawing operations, the speed being determined by the ability of the operator at the loading station, although certain objects can be supplied *en masse* on to a smooth table from which they are transferred to the turntable, the rate of feed being thus much increased. For some necking operations the table carries a series of pegs on to which the drawn blanks are placed and are then carried under a die which performs the necking. Successive operations occur when it is not possible to obtain the desired form with one die only, an example of this being seen on a double-crank press, the wide

slide of which holds the three tools, the turntable bringing the cups successively under them. Springs or positive extractors are arranged in conjunction with turntables. Fig. 196 shows a press having a 12-hole turntable.

Die-cushions.—The counter-pressure applied by a cushion in a combination die enables single-acting presses to be used for a wide range of blanking and drawing operations. For comparatively shallow draws a rubber buffer is suitable, but springs are provided in many instances as an alternative, regulation of the degree of pressure in either type being made by means of screws. Several designs of pneumatic cushions are available for performing the same function, one with moving cylinder and the others with moving pistons. The differences are seen in Figs. 197 and 198, from which it will be clear that the pressure of the apparatus is transmitted by pins to a pressure plate, and thence by other pins to the blank-holder. The combined punch and drawing ring descends and cuts the blank, and then presses it against the blank-holder, after which the drawing operation takes place. The objection to the spring device is that it causes increase in pressure during the descent, but this is not the case with the pneumatic cylinder Multi-cylinder outfits are made for large work. Installing a multi-cylinder set in the table of a double-action press converts it to triple action, as after the main draw has been performed, a counter-draw can be made. Pneumatic cushions are sometimes mounted in the press slide to act as an additional blank-holder.

Marquette Die-cushions.—These are built in many types for different powers and methods of application, and a résumé of these is given below.

The simplest design is supplied for light high-speed operations on covers and bottoms, caps, rings, etc., in thin metal, and the unit is self-contained, requiring no tank, as the air is taken direct from the pipe-line and goes through a check valve with a gauge which regulates and records the pressure desired. A record can thus be kept so as to be able to set the cushion quickly for any job. A handle is turned until the gauge shows the correct pressure. The constant uniformity of pressure during the draw saves losses from wrinkling or tearing. The pressure is automatically held at the pre-set figure, independent of variation in the line pressure. Installation is simple, as only two screws are required to attach the cylinder under the bed, and a quick-lock coupling to the hose. The four sizes of this outfit rate thus :

Diameter of piston	inches	4	6	8	10
Maximum height	inches	9	10	10	11
Maximum draw, standard	inches	1	1	1	1
Largest diameter light-gauge blank	inches	4	6	8	10
Blank-holding pressure, 80 lb. line	tons	½	1½	2	3
Weight of cushion and piston	about lb.	20	30	35	40

Another simple style (Fig. 197) is designed so that it can be substituted for a rubber bumper or spring outfit, without the necessity of doing any

machining work; this is due to the fact that a central stud is fitted to the cylinder and holds it firmly in position. The same system of pressure control and direct-line supply is adopted as with the other type mentioned earlier.

Fixed-piston and Moving-piston Cushions.—A range of cushions is made which is run in connection with a surge tank, one for each unit, this being essential in order to give a uniform pressure for the full stroke, the air in each equipment being displaced into its tank to obtain various pressures for different jobs. These are available in two different designs, one with a fixed piston and moving cylinder (Fig. 198), the other the direct opposite (Fig. 199). In the first case the piston is attached to a hollow shaft secured under the press bed; in the other case the cylinder is supported by a plate and bolts. The fixed-piston model is more efficient than a rubber buffer.

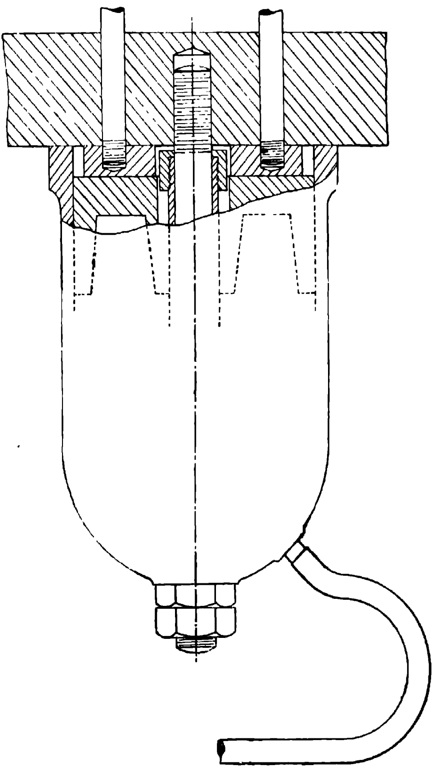


Fig 197—Light-weight high-speed Marquette die-cushion

Single-piston and Double-piston Cushions.—The object of making double-piston cushions (Fig. 200) is to increase the power without greatly increasing the rise, thereby catering for restricted accommodation. Duplicated cylinders receive the pistons, the method of attaching the piston rod to the bolster plate being by a thread. The sizes of the cushions are coded by symbols giving the bore of cylinder plus the stroke, and

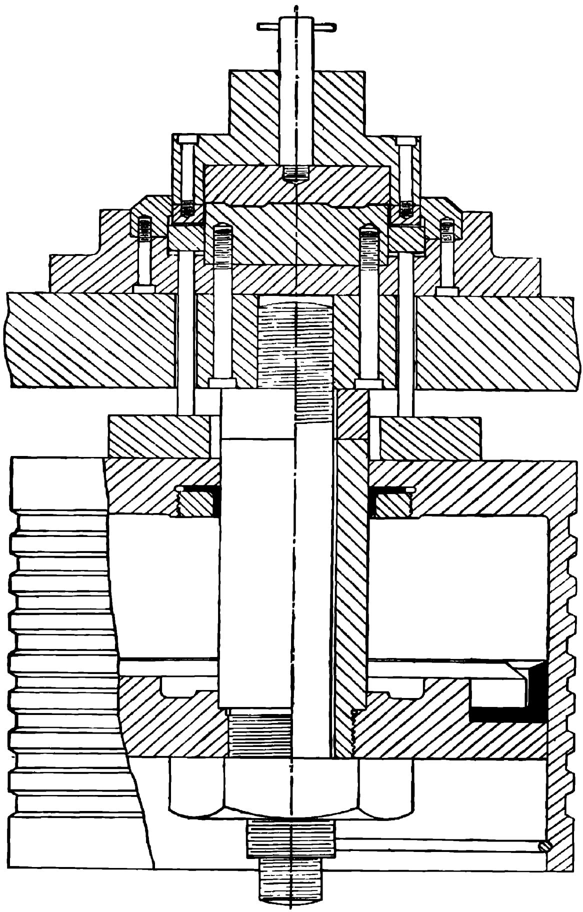


Fig. 198.—Marquette pneumatic die-cushion of moving-cylinder type

twenty-two standard sizes are manufactured in both single- and double-piston types. The smallest single unit has a piston diameter and stroke of 4—2 inches and gives 0·6 tons pressure from 100 lb. air supply, while the largest is rated 12—6, and affords 5·6 tons pressure.

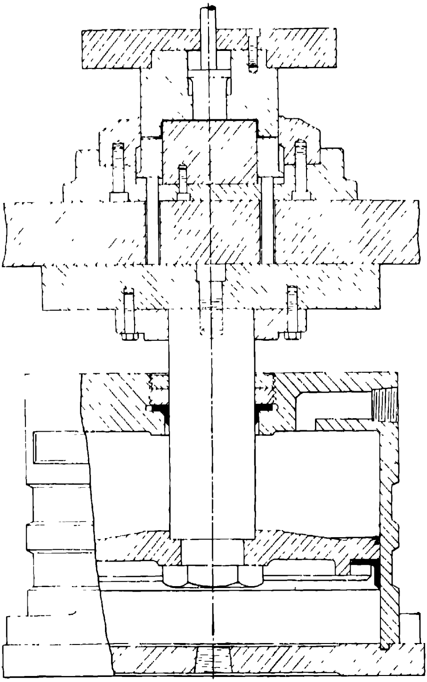


Fig 199.—Moving-piston type of Marquette die-cushion

Triple-piston Cushions.—To obtain still greater power for heavy presses, three pistons work in three cylinders, and a pressure of 186 tons can be obtained from the largest set, which has a 40 inches bore.

Multiple Mountings.—Two, four, six, or more cushions are employed in the larger presses, there being as many as sixteen in big double-crank machines, these being suspended from rods and a bottom plate. Spacer blocks inserted between the plate and the bed increase the rigidity.

Telescoping-cylinder Cushions.—A compact design is obtained by a double-cylinder construction in which the inside cylinder forms the piston for the outside cylinder, and there is a separate piston for the inside cylinder, consequently little space is occupied for the length of draw. This arrangement (Fig. 201) provides extra long guides for the outside cylinder, and prevents deflection of the movement. The combined pressure capacity of the outer and inner cylinders with their respective pistons is equal to that of double-decked cylinders of the same piston area.

Cushion Beds. — A variation of the separate blank-holder design is that of building cushions integrally with the press bed (Fig. 202), a scheme conferring many advantages, such as the avoidance of deep pit foundations,

otherwise necessary to accommodate cushions underneath the bed, and a considerable reduction in the cost of foundations. Pressure tanks are not wanted, as the bed has cored chambers around the cylinders acting as a reservoir for the displaced compressed air which flows from the cylinder into the space surrounding it. Most of the piping and joints are eliminated, and greater rigidity is achieved. The number of cylinders may be varied; two can operate two pressure plates working together with uniform pressure, or, alternatively, independently.

If necessary, six cylinders can actuate three pressure plates, two cylinders to each plate, the plates working together or independently with either uniform or three varied pressures.

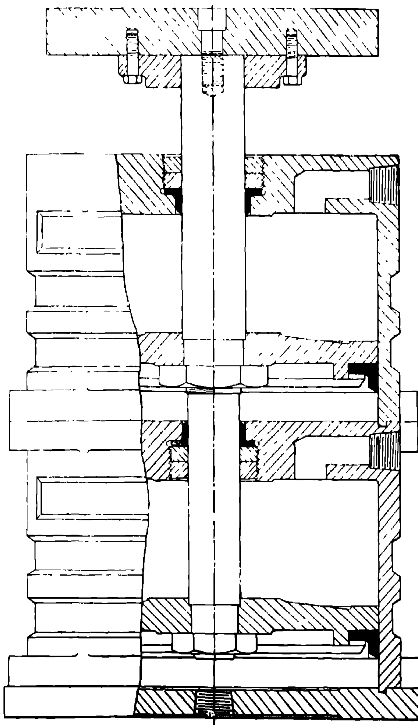


Fig 200—Double-piston die-cushion. (Marquette)

Hydro-pneumatic Cushions.—Pressures ranging from five to ten times those given by the pneumatic cushions are delivered by an oil cylinder fed from a tank into which the compressed-air supply is led. A relief valve controls the drawing pressure. Two-step or varied pressures can be arranged, so as to impart a heavy blank-holding grip at first, then a lighter one to complete the draw. The cushions may be built into the press beds to make a very compact unit, and the surge reservoirs are cast around the cylinder (Fig. 203). In one example of a very large press the cushions are divided into five independent units: five double-action dies may be worked independently at the same time, or all the cylinders can be syn-

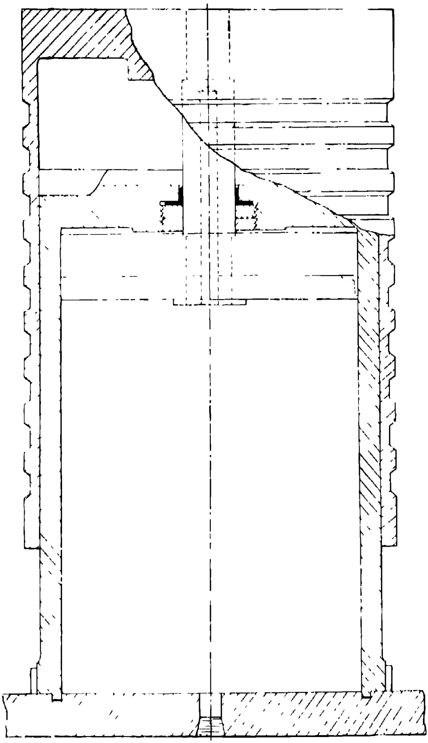


Fig 201 —Telescoping-cylinder design of Marquette die-cushion

chronised to act together.

Rotary Valve Control.—For the most effective control and timing of the action of cushions and knock-out pads or lifting cylinders, a rotary valve control is utilised, driven by a chain from the press crankshaft and turning cam drums, which revolve once for each stroke of the press. Great accuracy of timing is obtained by adjusting the cams (in T-slots) which operate poppet valves giving rapid action.

Hydro-pneumatic Locking Devices.—An application of the hydro-pneumatic action is that of locking devices for both pneumatic and hydro-pneumatic die-cushions. The purpose is to hold down the pressure pads on single-acting presses, also on double-acting presses until the slide has receded and left the die, thus preventing the pressure pad from striking the bottom of the stamping before the blank-holding pressure has been released. They are also used for delayed stripping in both slide and bed, and for raising the piece in the die after the up stroke so that removal may be done by hand. When used with pneumatic cushions the locking device consists of hydraulic cylinders connected to the pressure pads, and suspended under each pneumatic cylinder. The sequence of action is, that as the drawing slide comes down and strikes the pressure pad, the piston of the locking device is pushed down with it, causing the oil to move from the lower side of the piston to the upper side through

ball check valves and a valve port. When the pressure pad and the locking-device piston are at the bottom stroke the air-cylinder piston which actuates the locking device closes the return valve to prevent any

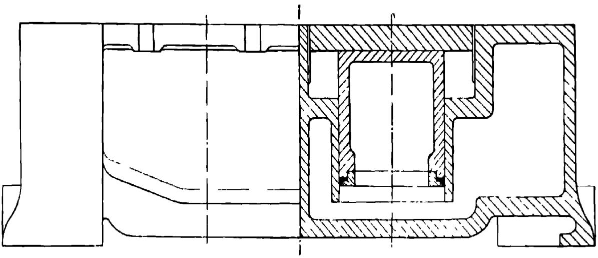


Fig. 202.—Marquette pneumatic cushion bed

oil from returning from the upper piston back to the lower piston, this action locking the pressure pad The air cylinder is arranged to actually push the locking-device piston and the pressure pad down a little further, in order to overcome any tendency of the pressure pad to creep back a little because of air trapped in the oil or in the packing.

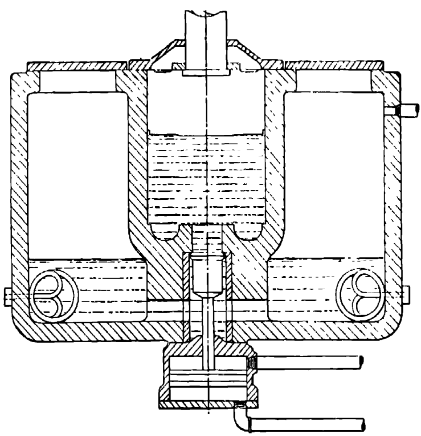


Fig. 203.—Hydro-pneumatic die-cushion. (Marquette)

Two units of the rotary control valve provide the proper timing of the dwell, and the up-and-down movements of the pressure pad. The cams are set to exhaust the air on one side of the air cylinder at the correct moment, usually at about mid-stroke up, and admit air on the other side of the piston to open the relief valve which permits the oil to return, breaking the lock, and allowing the pressure pad to return to its top position. The Marquette equipments are made by the E. W. Bliss Company.

The Simplex Drawing Device.—A purely mechanical equipment which enables a single-action press to do the work of a double-action cam or toggle press is shown in Fig. 204. This is made by Joseph Rhodes & Sons, Ltd., and is located under the bed of the machine. The same general principle is followed in different sizes, those for the heavier duties necessarily having certain constructional modifications. The blank-holding pressure is automatically provided by the mechanism,

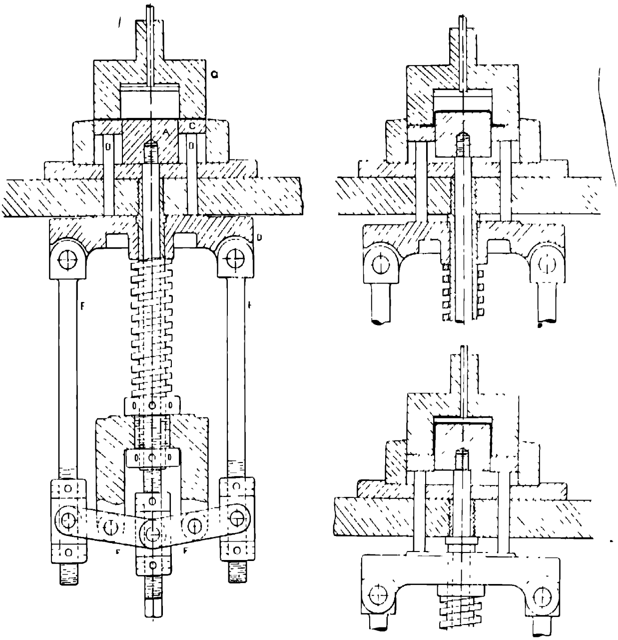


Fig. 204—Simplex drawing device for use on single-action presses

being self-forming and self-compensating, according to the thickness of the metal being drawn, there being no need to sort out varying batches of blanks as regards thickness. In mild steel two-thirds of the diameter can be drawn at one stroke without trouble, an example of this being provided by a steel stew-pan which is drawn in 18 s.w.g. 10½ inches diameter by 8 inches deep, and as the pressure is automatically regulated, difficulties with tearing or wrinkling are eliminated. Cutting and drawing may be done at the same operation if necessary.

In its simplest form the arrangement consists of a tube screwed to the bed, the attachment being suspended therefrom. A rod passes through the tube, to be screwed to the forming block A of the bottom die. When working, the pressure pins B, B are forced down by the ring C, and they thrust down the platform D, in turn causing levers E to move the toggles F, lifting the centre rod. As a result, the block A rises into the top die at a rate proportionate with that of the downward movement. The blank offers resistance to the upward motion of the forming block, by which the requisite drawing pressure is obtained. The spring seen is not used for the drawing operation, but serves to bring the levers back to the normal position, and eject the stamping. As the bottom block travels upwards in accordance with the downward movement of the top die, a short stroke is therefore projected. For example, a stamping 4 inches deep only requires a stroke of 6½ inches (allowing ½ inch for clearance) as against 8½ inches when using a double-action press. The heavier designs have toothed levers at the bottom, instead of the pivoted levers, the teeth on their radial faces meshing with rack teeth on each side of the central rod.

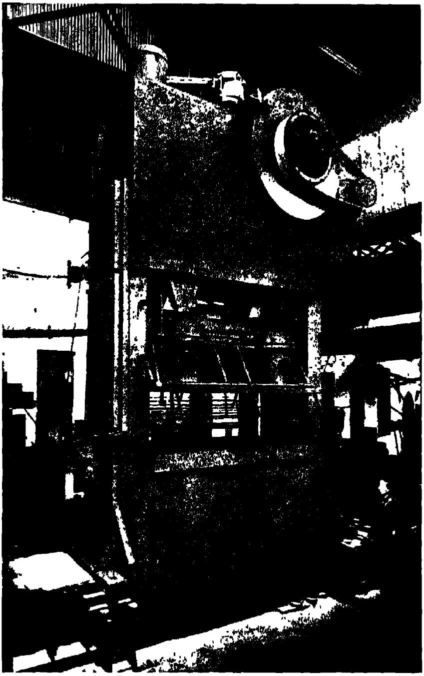


Fig. 205 —Showing the deep frame required below the bed of a large press (Wilkins & Mitchell, Darlaston)

Press Controls.—The hand lever or pedal control which is usual in a large number of instances is varied in order to provide a greater measure of safety ; for instance, a two-handed control minimises chances of injury to the operator's hands, since both hands must operate the starting levers

before the press will run. On large machines mechanical means are superseded by pneumatic or electric controls.

Press Foundations.—The form of foundation used depends on the type of press and the manufacturer's design. The biggest presses are supported on cross-girders bolted to a pair of longitudinal girders, and other cross-girders are provided for carrying the driving details. The depth of the pit depends on the operator's requirements for height, and for the projection of an extractor. The deeply based press seen in Fig. 205 is the one which does the pressing of radiator cowls, as shown in Chapter 8, Volume II.

CHAPTER 11

COINING AND OTHER OPERATIONS

COINING is a term describing the cold compression of several classes of products. The blank is placed in a die which is closed, or practically so, and becomes squeezed or die-forged into shape purely by the flow of the metal, great pressure being required for the operation. In its broadest sense the process is applied to forming coins, medals, dials, embossed plates, spoons, forks, knife handles, turbine blades, watch cases, links, etc., and to the sizing and planishing of stamped objects. Apart from any question of forming, many metals are strengthened and made more resistant to wear as a result of the compressive action, and subsequent machining operations are often rendered unnecessary. In order to obtain the high pressures without spring or deflection, or damage to the dies, an extremely substantial type of framing is essential, and the mechanism must also be very strongly constructed, as considerable overloads are liable to occur, and the possibility of these must also be taken into account. The heaviest machines give a maximum pressure of 3,000 tons, and as a consequence special features must necessarily characterise the design and construction of coining presses, these not

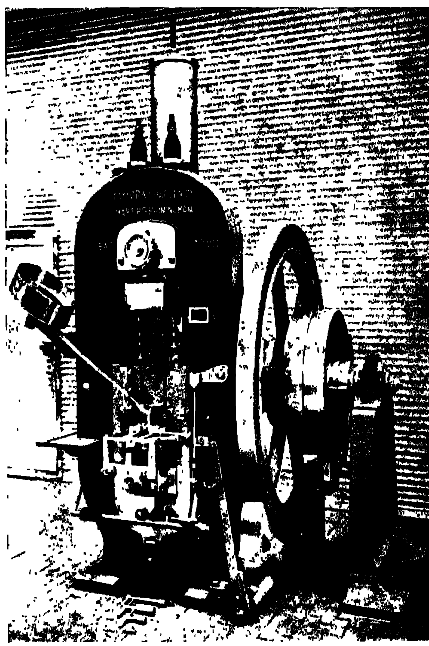


Fig 206 —Coining press fitted with automatic hopper feed

being usually found in other types of press, nor indeed would they be necessary.

Principle of Operation.—The coining press has to exert a heavy pressure, increasing towards the end of the stroke, and since the area of the work is comparatively small a very close design of framing can be employed. In the smaller sizes a solid closed frame is used (Fig. 206), the built-up tie-rod construction being employed for larger sizes ; a steel casting or a steel forging is used for the former type, the gap forming the slides. The dies are machined from solid steel blocks. The methods of operation and adjustment applicable to other presses do not suit the exceptionally severe duties incurred in coining, and the slide is moved by a toggle or knuckle-joint device, being adjusted by a wedge that gives solid metal-to-metal contact. Two forms of knuckle joint are to be found in the different designs of coining press. In one, Fig. 207, the connecting rod from the crankshaft is pivoted on each end of a pin lying between the knuckles, which are free to swivel on the pin above and below. The pins and bushings are hardened and ground, and plentifully cut with oil grooves, through which the lubricant is distributed from the passages to which it is supplied by a pump, the flow returning to the pump from the bath in the slide block. The other scheme embodies the use of renewable toggle blocks, which are carried in holders provided with bearing pads for them to rock against (Fig. 208). Other features which may be observed in this drawing are : A, the top adjustment which is effected by a screw-actuated wedge ; B, the pressure adjustment to bottom die ; C, a setting to regulate the lift of

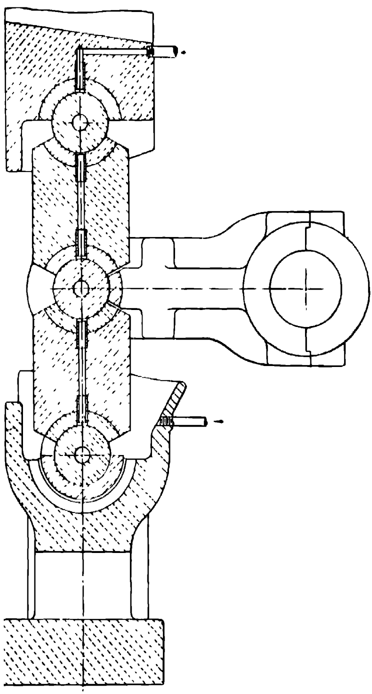


Fig —Toggle-joint motion of Bliss coining press

the bottom die; D, a spherical seating, which permits adjustment of the die-face level in order to equalise the impression on the work; E, the top die holder, which is removable and replaceable quickly without any resetting of the die; F, the cams, which lift bottom slide and eject the coin; G, the spring balance; and H, the delivery chute. The feeder chute has a connection with the automatic clutch, which stops the press when there are no more blanks left, thus preventing the dies from being damaged by "clashing."

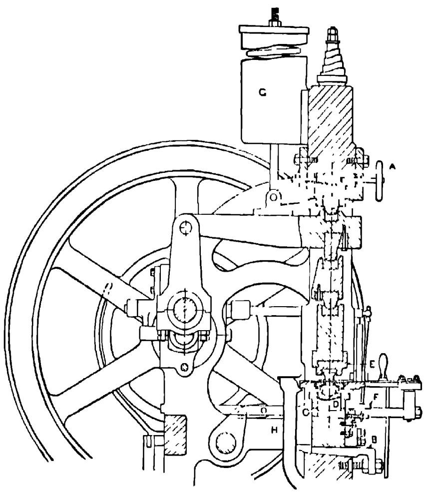


Fig. 208—Taylor & Challen coining press.

The modern type of press, which is illustrated in Chapter 8, Vol. 2, differs from the usual construction in that the top die is carried in a hammer lever instead of a slide, which renders the press more immune to the effect of coins having irregular relief. The adjustment to the top die is effected by four parallel screws in the centre link of the toggle movement, and knuckles of the roller type are fitted. A lifting gear is provided for use when removing the collar plate to change the collar or bottom die. The particulars of this machine are:

Pressure exerted at bottom of stroke	250 tons
Stroke . .	$\frac{7}{8}$ inches
Adjustment to slide	$\frac{1}{2}$ inch
Strokes per minute, usual	80
Floor to collar plate	36 inches
Motor . .	10 h.p. at 720 r.p.m.
Overall height .	124 inches
Net weight .	121$\frac{1}{2}$ cwt.

The extractor mechanism shown in Fig. 209 enables a press to run at high speed, as many as 140 strokes per minute being possible. The action of the extractor mechanism is as follows: The cam A on its forward stroke impinges on the pivoted pawl B and imparts an upward movement to the bolster slide C, which carries the lower die, thus ejecting the coin to the level of the feed table from which it is swept off by the

feed fingers (not shown), and slide down the sloping table into a receptacle. The feed fingers immediately place another blank in the space in the collar formed by the falling of the bottom die.

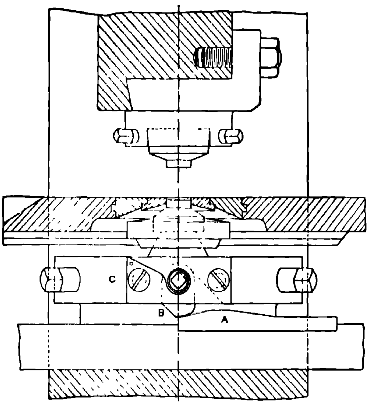


Fig. 209—High-speed extractor mechanism of Taylor & Challen coining press

Hand-feeding Attachments.—When hand feeding has to be performed, an attachment with lever-fed slide is provided which transfers the blank to the die as soon as the previous piece has been ejected, an interlocking device preventing the press from starting unless the feeder slide has been pulled right back. In the case of an embossed object having a centre hole, a central locating plug becomes necessary, the work being placed by hand upon this, extraction being by means of a hand lever. When a chute feed is employed, a special feeder can be fitted to deal rapidly with small coins. The feed fingers close together, allowing a very slight clearance for the blank, but in addition there are two cover plates, which are clear apart when under the coin chute, but overlap the coin when it feeds forward, and so prevents it from jumping out. A twisting device is provided which gives a turning movement to the top die whilst coining is in progress, thus enabling a clear impression to be reproduced with the least possible pressure on the dies.

Preparation of Blanks.—The blanks are punched out in roll-feed presses using single or multiple punches. In a machine having three punches, an output of 450 blanks per minute, each $1\frac{1}{8}$ inch diameter by $\frac{1}{16}$ inch thick is possible, a marking machine employing a rolling process thickening up the edges before they are fed to the coining press. With an automatic rotary hopper feed the blanks can be put in haphazard, and they will separate themselves and pass down a chute to the marking wheel at the rate of 600 per minute.

Testing Machine for Coining Presses.—In order to determine the pressures required to produce perfect coins when new designs are in preparation, Taylor & Challen supply a hydraulic press working at pressures up to 200 tons and driven by a pump mounted at the side on the same bedplate. The bottom die and the collar, together with the blank which is inserted in the collar, are moved upwards by the ram until

contact occurs with the top die, the gradually increasing pressure being shown on the gauge, in tons and fractions of a ton.

Automatic Feeds.—Blanks other than coins and medals require various kinds of automatic feeds, the type chosen depending on the shape of the piece. A modified type of magazine and pusher feed can be arranged in many instances, or a chain feed may be more suitable. The turntable method is also applicable for some articles. Another system is to have a smooth rotating disk upon which the blanks are placed.

HORNING PRESSES

Horning or Grooving Presses.—The closing of side seams demands the services of presses or grooving machines, the differences in the mode of operation depending upon whether dies or grooving rollers are used. In the tinsmith's small grooving machine, hand gearing is employed to wind the roller along the seam, the same principle being employed in power-driven types. As an example of the power-driven type, mention may be made of a machine for handling pipes up to 3 feet long which has belt and gear drive, with instantaneous stopping, starting, and reversing motions. The grooving bar is pivoted and evenly balanced, and when the roller carriage has reached the end of its travel it automatically unlocks the end of the bar, which tips downwards, thereby enabling the grooved pipe to slide off. In order to obtain maximum output, the reversing motion is adjustable so as to give only the required length of travel necessary for the article, no matter whether this be long or short.

Fig. 210.—Foot-lever grooving press. (Rhodes.)

Horning Press.—The usual form of foot-operated horning press consists of a narrow frame bolted on the bench, carrying a pivoted arm with a blade which comes down when the pedal is depressed. The horn lies at an angle to facilitate placing on the work, different horns being substi-

tuted to suit the work size, while various-shaped horns, either round, elliptical, or of any other form, can be used (see Fig. 210).

Power-driven presses are sometimes of normal width, when used for general purposes, and the table is removed or swung aside (Figs. 211, 212) for the insertion of a horn. When specially built for horning, a narrow frame is employed, and the horn is fitted into a hole or bolted against the face. A double-horn press is built for use in the construction of 5-gallon tins which horns two body seams simultaneously. Wide presses are supplied for certain purposes, such as closing the sides of perambulator bodies, the boxes of grass cutters and so on, a two-crank model dealing with these. An end-wheel type of press is employed for heavy work, such as kegs and drums, the horn projecting from a lug cast on the frame, with the slide reciprocating in guideways, similar to the practice adopted in punching presses (Fig. 213). Another mode of operation, for long articles, is to extend the driving shaft under an arched frame, the outer end of which supports the shaft, while the long ram moves in guideways at each end. Two eccentrics actuate the connecting rods pivoted to the ram.

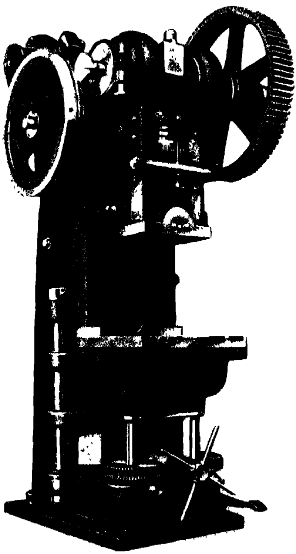


Fig. 211.—Large horning press with heavy swivel table. (Rhodes.)

Folding and Grooving Presses.—The complete process of folding and closing is performed in machines of the end-wheel type, which have bending bars and pressure bars (Fig. 214) moved by cams, with automatic support to the mandrel, which leaves it open at the proper time, but supports it during the folding and grooving operation. An inclined-horn press (Fig. 215) is built on somewhat similar lines.

SEAMING MACHINES

Seaming Machines.—A large variety of machine types are employed in the operation of seaming the ends of cans, drums, boxes, etc., these being either small or large, hand, semi-, or fully automatic, some being fitted with dies, while others have rollers. Some of these machines do only one end at a time, while others are designed to do both ends simultaneously. Machines for combined flanging and seaming are described in Vol. 2, Chapter 3.

Hand Seamers.—The lightest class of seaming machine is held in a support on the bench, and has double arms in which run the spindles, with a setting-down motion operated by either a handle or a screw for the upper one. The smallest-capacity machine of this type is designed to handle work from 10 inches deep and downward to $2\frac{3}{8}$ inches diameter. Another bench pattern obtains the pressure from a foot-operated lever, and is equipped with a set of supporting disks in standard sizes: straight—5, $5\frac{3}{4}$, 6, $6\frac{1}{2}$, and 8 inches; taper—$4\frac{1}{8}$, $4\frac{3}{8}$, $6\frac{1}{4}$, $8\frac{5}{8}$, and $10\frac{7}{8}$ inches. In another instance the pressure of a hand lever forces over the rollers, the drive being either by hand, wheel, or belt pulley. The chucks and rollers are reversible, so that when one end is worn the other end can be used, giving double life. Tops and bottoms of cans from 2 to $6\frac{1}{2}$ inches diameter and from 2 to $8\frac{1}{2}$ inches high are dealt with. Fig. 216 shows this machine.

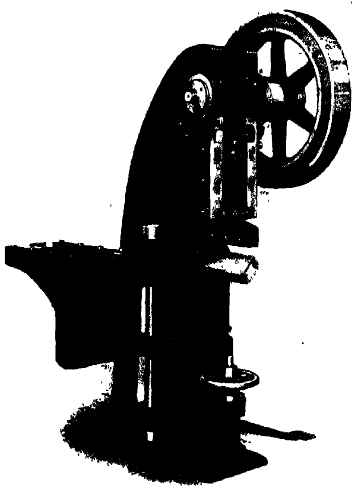


Fig 212 —Horning press fitted with swivel table for wiring

Power-driven Seamers.—These are of the vertical pattern, and are available in the semi- and fully automatic types. In some of these the body is rotated, while in others the body is stationary while the seaming process takes place. The simpler designs embody a column with a top spindle driven by a belt pulley, or a belt pulley in conjunction with gearing may be employed, control for the rollers being by means of a

lever. Spiral gears afford the smoothest form of drive to the spindle, particularly if a friction clutch is incorporated, working in conjunction with a brake. The latter is to stop the spindle instantaneously, it being more convenient to clamp cans, especially large ones, while the spindle is stationary. The approximate output for medium-sized cans would be about 1,500 per hour.

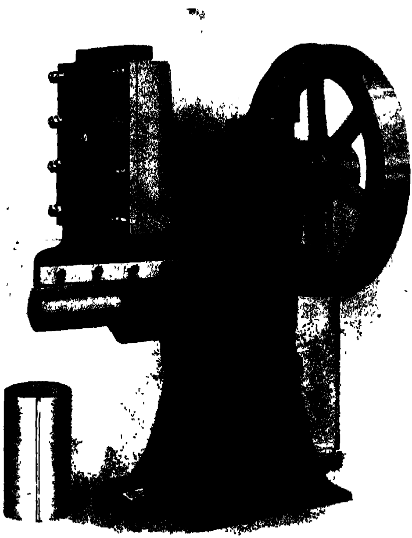


Fig. 213.—Rhodes' horning press for kegs and drums

Another hand-pressure seamer has the lower spindle driven through bevel gear from the pulley shaft, the upper disk being pulled down by a lever. This deals with vessels up to 18 inches diameter by 24 inches long, made in 20 s.w.g. sheet, the output being from sixty to seventy-five per hour. In a heavier construction, having the pressure applied to the seaming rollers by screw and hand wheel, about fifty drums per hour can be handled, the limit of dimensions being 30 inches diameter and 42 inches long, the power required to drive the machine being $7\frac{1}{2}$ h.p.

A sliding table (Fig. 217) is provided for operating the internal chucks required for seaming the cones on tin bottles, or, alternatively, the table is constructed so that it can swing. Sometimes a rim-rolling attachment is included, enabling a body to be seamed on the bottom, and wired on the rim.

Fig. 214.—Action in automatic side-seam locking machine. (Moon Bros., Ltd., Birkenhead.)

Mechanical-pressure Seamers.—Instead of forcing up the rollers by a hand lever, cam action is arranged in a good many different types of machines, the cam functioning when a treadle is depressed (Fig. 218). One such machine will give an output of about 100 gross per day, up to 7 inches diameter. A modified design handles square, elliptical, and

irregularly shaped tins. The same idea is to be found in machines handling vessels of large capacities; for example, drum seamers are made for diameters up to 24 inches, the drum being placed on the chuck mounted on the adjustable table, which is raised by a lever, while pedal control starts the drive. The pressure is regulated for various flange widths, and there is an arrangement which ensures tight seams even on containers having grooved side seams. The following are the brief particulars of the largest model:

Maximum diameter of drum	24 inches
Minimum diameter of drum	11 inches
Maximum length of drum	42 inches
Minimum length of drum	10 inches
Maximum gauge of metal	14 s w.g
Power to drive .	15 h p.

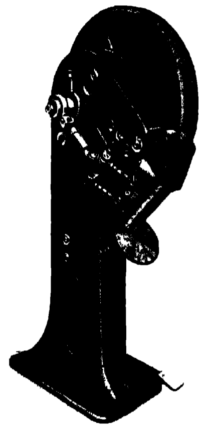


Fig. 215.—Inclined horn type of folding and grooving press (Rhodes.)

Safety Guard.—To prevent risk of the operator being injured by the lid flying out, a wire guard may be attached to the machine, this being pivoted to rise out of the way during loading. As soon as the clamping has been done, and before the drum turns, the guard has dropped automatically to the safety position, where it is locked by a cam. The act of de-clamping automatically raises the guard clear for removal and reloading.

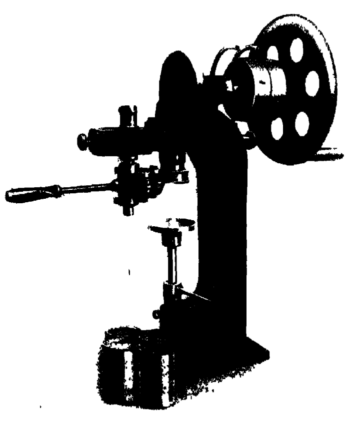


Fig. 216.—Rhodes' bench seamer.

Continuous Feeding.—With two operators, an output of five drums per minute is possible with a four-platform drum seamer (Fig. 219), the units being brought around automatically to the seaming position. The turntable is actuated by a worm-operated Geneva motion acting directly on the turntable spindle. One attendant feeds and the other inverts the drums after one end has been seamed, so that they are ready for seaming the other end. The sizes handled are, diameters 16 to 22 inches, and lengths 19 to 36 inches.

Stationary-body Machines.—A different class of seamers performs the action by means of four rollers in the spindle, whilst the body is stationary. There is no torsion, as with revolving cans, and no side pressure is put on the spindle; moreover, when seaming containers which have already been filled the contents remain undisturbed. The rollers comprise two first-operation and two second-operation shapes, the first pair tucking the can end edge under the flange of the body and slightly curling both of them inwards, and the second pair following to flatten the seam tightly. About 2,000 cans per hour can be seamed by machines of this type, elliptical and rectangular, as well as irregular cans, being also seamed by this method. A heavy type of machine handles cement drums, etc., up to 24 inches diameter, seaming on the tops after they have been filled. The counter-balanced spindle works in an arm standing out from girder uprights, and a long hand lever controls the descent of the spindle. Fig. 220 shows a machine for petrol tanks, and Fig 221 one for closing filled cans.

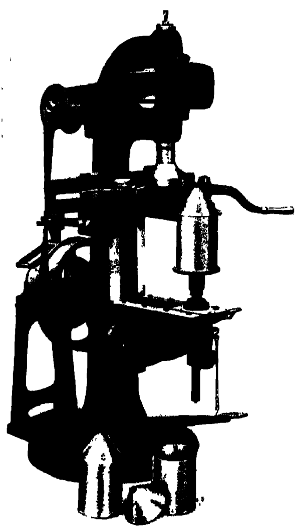


Fig 217 —Double seamer provided with sliding table for operating internal chucks. (Rhodes)

Automatic Lid Feed.—A magazine-feed attachment to the stationary can seamer eliminates the necessity for hand placing of lids or bottoms. The lid reaches the can, and both are held by spring pressure against the chuck, about 2,000 closures per hour being obtained.

Full Automatic Machines.—The combined working of a rotary and slide feed for bodies, and a magazine feed for lids, is seen in an automatic machine that attaches the lids to empty or filled cans at the rate of one per second. It has a positive no-can, no-cap device, and a marking apparatus for the caps. Diameters from 2 to 4¼ inches are handled.

A speed of 150 empty cans per minute is secured on an automatic machine which has four seaming heads for the circular seams, and four for the longitudinal seams. When seaming on lids of filled cans the output is about eighty per minute, and the cans, which are tranferred by a conveyor to the heads, do not rotate. On a certain job two machines are employed; on one machine the top is seamed, and the can then automatically inverted,

when it is conveyed to the second machine where the other end is seamed, the output being 12,000 square cans per day.

Simultaneous Seaming.—Some machines will perform the seaming of tops and bottoms simultaneously, special seaming roller guides accommodating differences in height due to faulty shearing or flanging. The seams come out clean and regular, and the body does not suffer twisting.

Seaming by Dies.—The direct stroke of a die in a power press may be applied to close seams, and there are squeezer machines that seam flat tops and bottoms on to bodies of petrol cans, biscuit tins, and suchlike. A mandrel holds the tin internally while the flat die slides approach at stations 90° apart. To seam the bottoms to round or rectangular tins a machine with an internal chuck and vertically moving die is employed, turning out one per second. Automatic action takes place as the bodies feed along a conveyor.

Crimping Machines.—Crimping or single seaming is effected both on roller-pressure machines and on those having dies. Some roller crimpers do one end at a time, others both ends simultaneously, all of them being of the belt-driven types. The die squeezers work by foot, or power drive, the dies sliding on a flat table, ordinary single seams, as well as hemmed-edge seams, being closed in this manner.

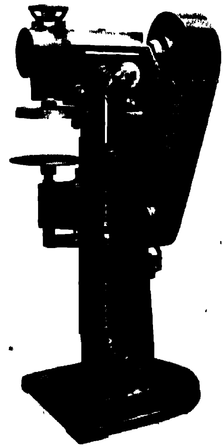


Fig. 218.—Mechanical-pressure double seamer (Lee & Crabtree, Ltd.)

WIRING

Wiring.—This process covers the curling or false wiring of edges, in addition to the real wiring in which a wire is enclosed, and machines with rollers as well as presses using dies are variously employed. A large amount of work of this nature is effected in power presses using curling or wiring dies, the resulting shape being a circular curl, or a flattened or clenched section, depending on the particular purpose for which the job is required. The curling die is so shaped that it causes the edge to roll up into a recess hollowed in the die.

Wiring Presses.—The various types of wiring press exhibit differences as regards the design of the beds in which an increased depth is afforded by the employment of either fixed type of bed construction, or through the use of an adjustable table. The movement necessary to bring out the die for the reception of the work is afforded by a slide working between gibbed guides. Some of the double-sided presses are furnished with a sunken

or U-shaped bolster deep enough to take the die, the sliding movement being obtained in the same manner.

One press specially built for wiring deep articles, such as buckets, dust-bins, gas-boiler casings, etc., has the drive taken from a shaft arranged underneath the bed, crankpins operating the rods which reciprocate the slide in a tall frame (Fig. 222). The dimensions of a bucket-wiring press of this description are: stroke, 14 inches; distance between uprights, 22 inches; maximum clear opening, 30 inches; bed, front to back, 20 inches; diameter of top platen, 17 inches.

Fig 219.—Continuous-feeding drum seamer. (Taylor & Challen, Ltd.)

Roller Machines.—Wiring may also be accomplished in the spinning lathe by the pressure of rollers, and there are several kinds of machine which curl or wire by a formative method of this description. Tinsmiths use the little bench machines turned by handle, and at the opposite end of the scale are the large automatic machines capable of taking plates or trays, chucking and curling them at a rapid rate. Edge-curling attachments often form a part of the machines used in the production of lids and bottoms for can-making, being located at the rear of the blanking and stamping presses. The curl enables automatic stacking and feeding to be done for subsequent operations, and the curl protects the sealing ring, which is later inserted. The attachment has an outer stationary ring and an inner revolving disk, driven from the main shaft of the press. The outer ring is mounted eccentrically in relation to the inner one, so that the can ends entering between them at the wide point will be forced to rotate by the inner disk, and to pass through a passage which gradually becomes narrower, thereby producing the curl. The rims of the outer ring and inner disk have grooves of the shape required to form the curl. If all the lids are accurately curled, a counting apparatus can be used to separate them automatically into batches of 100 as they slide down a chute.

Wiring and Edging Machines.—A comprehensive series of operations is performed by the Magee wiring and edging machines, which drive rolls of appropriate contour for the purpose. Those for wiring and edge turning respectively are shown in Fig. 223, adjustments being made according to the distance required between the peripheries and the shoulders of the rollers. Specimen operations are shown in Fig. 224, and the capacity of the machines is such that they will wire a length of one

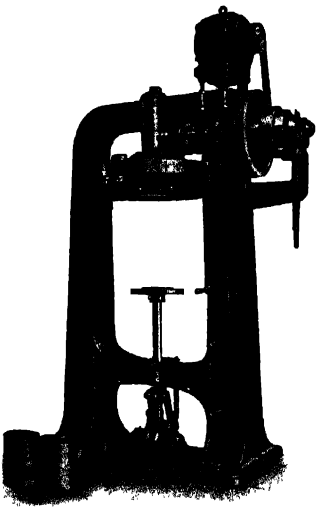


Fig. 220.—Semi-automatic double seamer of stationary body type

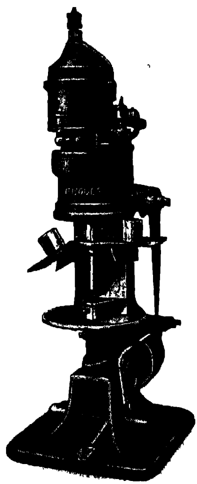


Fig. 221.—Semi-automatic seamer for filled cans.

mile in eight hours. Three sizes of machines are built, and there is also a special design for wiring internal circles. Eight standard types of hinged sub-frames or heads are supplied, so constructed that they can be quickly interchanged, leaving their set-ups undisturbed, and thus a rapid change-over from one job to another can be effected. A dial gauge is used for instant micrometer settings. Fig. 225 shows a general-purpose machine in which the motor is disposed in the column base. The heaviest size will take sheet up to 14 gauge, and wires to $\frac{5}{16}$ inch diameter. A combined action may be obtained by the use

of what is termed a disappearing roll, permitting the set of rolls to wire and bead at the same time at any point simultaneously with the wire, and also to terminate anywhere irrespective of the wire.

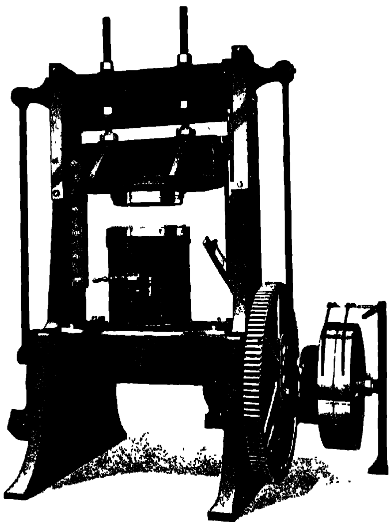


Fig 222 —Press for wiring buckets, dust-bins, etc. (Lee & Crabtree, Ltd)

Deep-throat Machines.—Fig. 226 shows the special type of machine built for wiring internal circles. This avoids the undesirable necessity of cutting through the sheet from the outside, and welding the parts together after the wiring has been completed, which method is, moreover, liable to change the shape of the sheet as it passes through the rolls. A hole as small as $7\frac{1}{2}$ inches diameter can be run, and as large as will go through the throat, which gives an outer circle diameter of over 5 feet.

MISCELLANEOUS MACHINES

Wheeling Machines.—Other classes of machines which employ rollers comprise the wheeling machines, and weld-crushing, rolling, and seaming machines. The first named is a simple affair (Fig. 227) which is utilised chiefly for smoothing and taking out creases from work previously shaped, such as motor wings and panels, although it is sometimes used for formative operations as well. The main shaft, which is turned by means of the handle, runs in ball bearings, which are also fitted to the interchangeable bottom rolls. A quick rise-and-fall movement to the bottom roll allows for the removal of the work without altering the pressure adjustment. The average depth

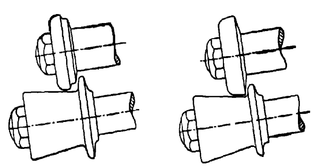


Fig 223 —Rollers for wiring and edge turning.

of gap is 40 inches, and attachments may be fitted for beading, seaming, and weld crushing.

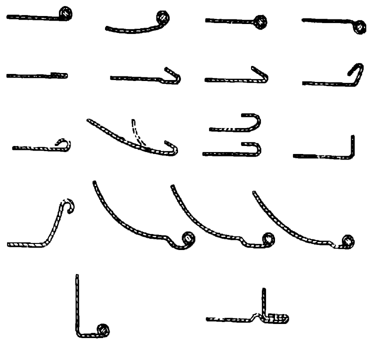


Fig 224 —Some of the shapes done on the wiring and edging machine

Weld-crushing and Rolling Machines.—The distinct operations of rolling, crushing, and seaming are effected on a machine constructed by the Oliver Machinery Co., Ltd., the change to any one of these operations being quickly effected. The frame is composed of two portions, the upper main element having slide adjustment by hand wheel to accommodate the setting of the seaming rolls, while the front section of the frame overhangs to permit a circular wing to pass underneath, the back part of the upright holding the driving mechanism. Both the top and bottom rolls are power driven, the former through a special jointed shaft, the latter by chain. The top roll has a quick vertical movement obtained by the use of a powerful ratchet lever, the bottom roll being raised similarly. The bottom roll may either be driven or allowed to run free if desired, a chain drive being adopted in order to enable welded work to be passed through between the rolls at right angles. A removable bracket is attached to the bottom ram, and carries auxiliary rolls in order to permit of welded

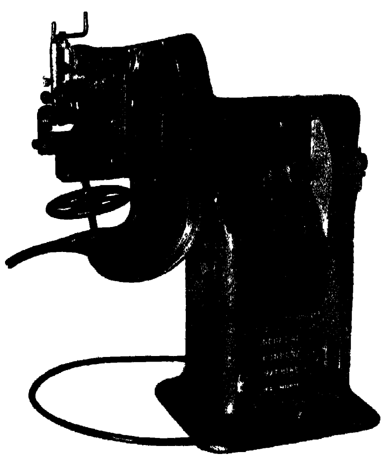


Fig. 225.—General-purpose wiring and edging machine (Oliver Machinery Co., Ltd.)

sections being rolled in a straight line. The 3-h.p. motor transmits the power through a Texrope, the reversing motion being obtained by means of a switch, while the control of the drive is effected through a clutch on the main shaft worked from pedals at each side of the machine (Fig. 228).

Riveting Machines.—Although much of the jointing in sheet-metal work has in recent years been subjected to a complete revision of methods necessitated by the great extension in the use of welding, there is still a considerable amount of riveting done, and various kinds of machines are installed for carrying out this work, the design of which depends on the size and class of work, and the quantity to be handled. Some objects are soft or delicate, demanding special care in riveting; again, there are jobs which can best be united by the use of a row of rivets, and all of these may be closed at one blow. Diversity necessarily exists in the shape of the frames used in the design of riveting machines, on account of the various shapes of work which have to be handled, but in many instances an otherwise ordinary press will be equipped with a special table, or anvil, or horn, to enable it to be used for riveting work. Hand or foot presses are used for light work (Fig. 229).

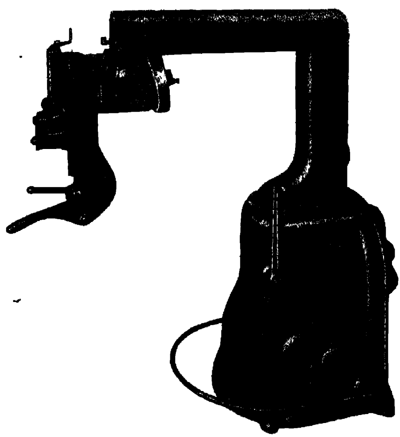


Fig. 226.—Deep-throat wiring and edging machine for internal circles (Oliver.)

Small Riveting Presses.—One of the simple types of riveting machine is that in which an eccentric end wheel is employed to deliver a single blow, an anvil of suitable shape being fitted on the bed (Fig. 230). Control is obtained by means of a pedal clutch. In this machine the reach from the centre to the back is 5 inches. Another single-blow press has a horizontal rocking arm at the end of which the snap is fastened, and the support lies in an adjustable slide overhanging the frame, components difficult to manipulate being thus handled more easily than on an

ordinary press. The riveting arm is rocked by an eccentric on the driving shaft close to the floor, and a rod connects to the tail of the arm. Rivets from $\frac{3}{16}$ to $\frac{7}{16}$ inches diameter can be driven on this machine (Fig. 231).

Window-frame Press.—For riveting steel window frames an end-wheel press, or one of the lateral-shaft type, is employed, the anvil being bolted to the facing on the standard with two screws for adjustment and prevention of slip (Fig. 232).

Tank Riveters.—For closing rivets in tanks, drums, and pipes a long mandrel must be employed extending from the press frame, and the end-wheel type of press is therefore used (Fig. 233). Mandrels range in length from about 3 to 6 feet, and the presses will close $\frac{5}{16}$-inch diameter rivets. A modified form of anvil is required to reach through a manhole and support the tank. To rivet up the ends of tanks a tall-framed press is required, and the long anvil, which is made of square section, tilts outwards on a pivot to facilitate removal of the tank, bodies having a depth up to 38 inches being accommodated.

Bucket-riveting Press.—For this work a press carrying a long anvil and the necessary closing tool is employed. The rivets are placed in position by a charging device, the first stroke making the rivets pierce their holes, while the second cups and flattens them. Employing two operators, sixteen gross of buckets can be riveted in a day.

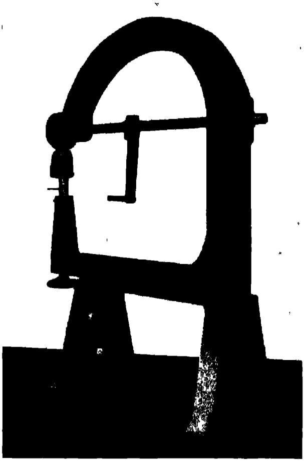


Fig. 227.—Wheeling machine for smoothing purposes. (Walter Frost.)

Rotary-blow Machines.—To increase the rate of production, and at the same time to ease the action of riveting, some machines embody a rotary motion combined with high-speed vibration. Both top and bottom anvils are driven, although the bottom one can be rendered inoperative if desired. A high-speed riveter incorporates a set of rollers running between revolving disks, and centring themselves by centrifugal force. The work is laid on the anvil and raised by a pedal, the punch moving upwards until it comes into contact with the rollers.. In combination with the rotary action the rivet receives 10,000 blows per minute. Four models of this class of machine are available, the particulars being as follows :

Capacity, diameter of head	$\frac{11}{64}$ inch	$\frac{1}{4}$ inch	$\frac{7}{16}$ inch	$\frac{5}{8}$ inch
Time required per rivet, seconds	2 to 3	2 to 3	4 to 5	6 to 7
Power required, h p. . .	3	4	8	1
Maximum distance, punch to anvil	$2\frac{3}{8}$ inches	$3\frac{3}{8}$ inches	$5\frac{1}{8}$ inches	$5\frac{1}{8}$ inches

An imitation of hand riveting is obtained in the Churchill machines, which are built in sizes for $\frac{1}{8}$-inch and $\frac{5}{16}$-inch rivets. Reciprocating motion is imparted to the hammer spindle by a hickory helve, pivoted on to the head casting, and actuated by a thrust block working between rubber buffers. A connecting rod goes through the thrust block, to transmit the motion from an eccentric on the main spindle. This method gives a series of sharp, definite blows, the spindle at the same time being rotated by means of a worm gear. A disk clutch with fibre lining is located in the main pulley, and controlled by a pedal, a brake which stops the hammer spindle in its highest position coming into action automatically on releasing the foot. Either countershaft or motor drive may be employed; in the latter case, a three-speed pulley permitting the hammer to deliver approximately 3,000, 2,150, and 1,540 blows per minute. A standard design of table is fitted, although a special form for irregularly shaped objects can be supplied if desired. The smaller-capacity machine requires $\frac{1}{2}$ h.p. to drive it and the larger one $\frac{3}{4}$ h.p. Fig. 234 shows a helve riveter.

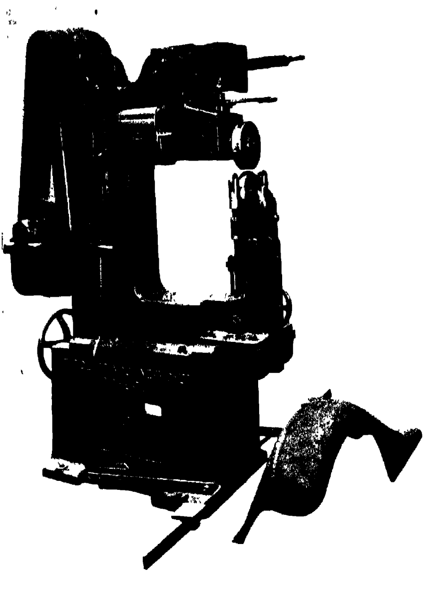


Fig 228.—Weld-crushing and rolling machine.

Spinning by the pressure of little rollers on a revolving spindle constitutes another mode of closing rivet heads.

Automatic Riveters.—The full development of light riveting practice is seen in an automatic machine which will place and head from 1,200 to 2,500

rivets per hour (Fig. 235). A hopper feed, with positive selector gear, supplies the rivets to the work, the two parts of the latter being pressed together whilst riveting is actually in progress, thus ensuring filled holes with tight joints. A pilot guide gives quick setting, and solid, tubular, or split rivets can be used, the change-over being made in a few minutes to suit any size or type of rivet up to $\frac{1}{4}$ inch diameter and $\frac{7}{8}$ inch long. An auto-feed pedal machine appears in Fig. 236.

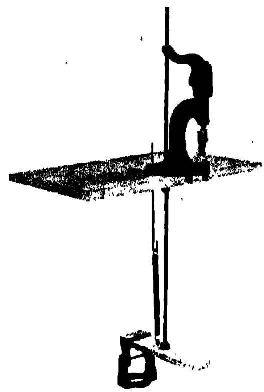


Fig 229 Foot-operated riveting machine (Bifurcated and Tubular Rivet Co., Ltd , Aylesbury)

Trimming.—The trimming of raw edges left on various sheet-metal articles which have been hand worked, rolled, stamped, or drawn, calls for the services of various kinds of machines, chosen according to the shape of the component, or the number of units which have to be passed through. The various types of spinning lathes are freely used for this operation, the trimming process being effected at the same chucking as that when spinning, beading, or wiring is performed, although sometimes the final process is carried out on another lathe. As already noted in Vol. 2, Chapter 2, rotary shearing machines can be used to trim curved and contoured stampings of any outline.

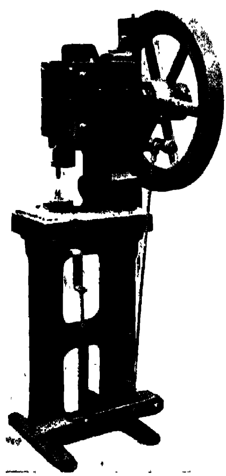


Fig. 230.—Light riveting machine (Walter Frost.)

Trimming Presses.—Dies can be operated in the power press to shear off the edges of any sheet by a lateral movement. The Bliss trimmer, which is an example of this, is a double-sided press with cam motion to the slide, and the upper die (Fig. 237), which is ground with sharp cutting edges, has a filler pad free to float on its surface. The lower die has its surface ground truly, and the projections or gauge pieces surrounding the cutting part of the upper die ensure positive and accurate alignment between the respective cutting edges of the pair. On starting up, the cam motion

Automatic Trimmers.—The resemblance to the lathe tends to disappear in some of the different designs of automatic trimmers which are available. One of the chute-feed types takes a case as it reaches the bottom of the chute, and moves it forward until it has entered a revolving die, whereupon trimming takes place. The mandrel retires, leaving the trimmed case in the die, from which it is pushed off

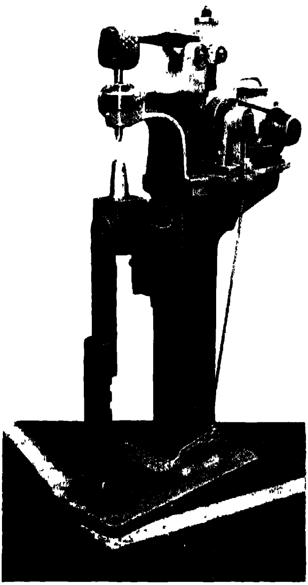


Fig. 234.—Elastic-blow riveter. (Burton, Griffiths & Co., Ltd.)

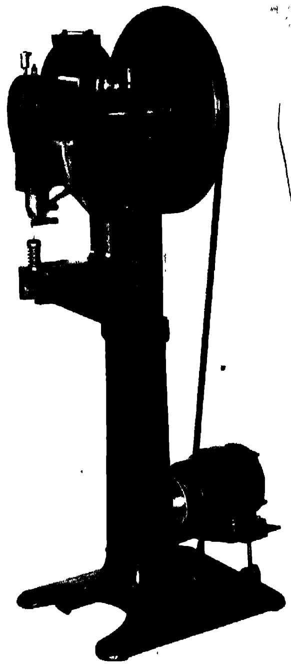


Fig. 235.—Automatic hopper-feed riveter. (Gaston Marbaix, Ltd.)

by an automatic extractor, to fall down another chute. The rate of production is sixty-four pieces per minute.

Barrelling.—A class of treatment which is somewhat related to trimming, but also goes beyond its scope, is that of barrelling, shaking, or tumbling. It is applied to the cleaning off of raw sharp edges on stampings and other pieces which have been cut, being a quick wholesale mode of accomplishing the process. Also of putting a smooth or burnished

finish on the articles, which may be sufficient for their purpose, or as a preparation for plating or other operations. Parts in iron, steel, copper, brass, gunmetal, nickel-silver, gold, silver, as well as bakelite and other plastics, are dealt with. Different methods are adopted according to the sort of goods. The principle is that of tumbling the objects in a rotating barrel, with or without an agent that will facilitate the action. Some shapes will mutually operate to effect the scouring process, others require mechanical assistance in the way of steel balls, iron rumbling stars, or steel scrap, which, however, can be used over and over again. The stars penetrate recesses.

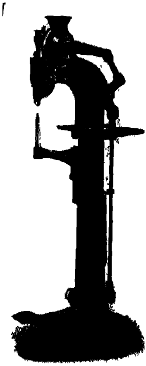


Fig 236 — Auto-feed riveter, foot operated (Bifurcated & Tubular Rivet Co, Ltd)

The preliminary action of scouring is done along with cleaning materials. Iron and steel pieces, if they have scale, need emery and oil in the barrel, but clean metal only requires Tripoli powder, pumice powder, or fine sand along with water. Hardened-steel articles, if they will not barrel alone, are scoured by the addition of steel scrap; and sharp sand or granite chippings, along with a metal cleaner, impart a silvery-grey colour. Copper, brass, gunmetal, and nickel-silver are treated by powdered pumice and water, while another way is to use coke dust and water. The burnishing of soft-iron and steel parts is performed in a barrel along with a number of bright, hard steel balls, covered with water, and a little soap powder added. Aqua fortis is sometimes employed to dip copper, brass, gunmetal, and nickel-silver before giving the same treatment as just specified. The difference with regard to silver and gold is that the cleaning medium must be saved, for recovery of the metals. Polishing of iron and steel can be effected in a dry barrel along with fine leather scrap.

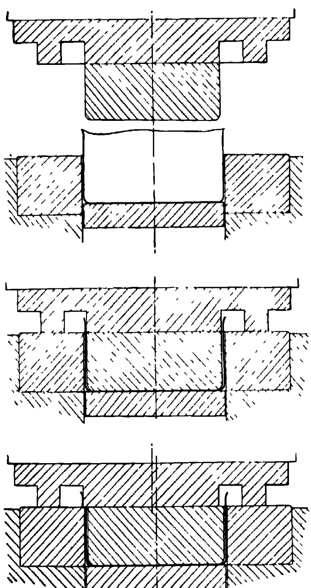


Fig 237 —Trimming dies which operate by lateral motion.

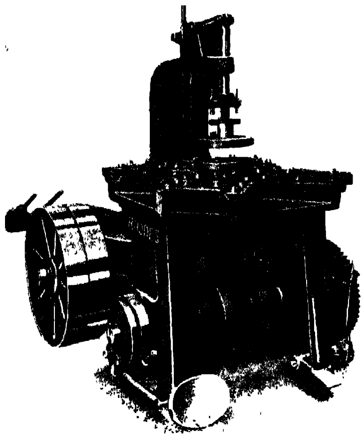


Fig 238 —High-speed box trimmer of sliding-die type

Barrels are made in various shapes, and some are closed, usually for horizontal running, while the open-ended types are set at an angle. The tilting arrangement is such that the barrel can be adjusted to the most suitable angle desired, and quickly lowered for emptying. The advantage of the open barrel is that the work may be examined at intervals without having to stop the rotation, and ingredients can be added similarly. Metal barrels are made in conical and polygonal shapes, and wood ones in round, hexagon, and decagon forms, hard maple or oak being the best wood to use, as it does not splinter, and has fine wearing qualities. Ordinary barrels measure from 16 to 28 inches diameter, but very small sizes are used by jewellers, silversmiths, and others, a hexagon barrel being mounted on each end of the spindle of a belt-driven head, each unit measuring about 9 inches long by 6 inches across the flats.

The speeds of barrels depend on the class of work, that of light character being run faster than heavy kinds; rates should not exceed 100 feet per minute for heavy objects, 150 for medium, and 200 for light pieces in a closed barrel. Speeds up to 300 feet per minute can be run, according to the sort of work, in the open-ended barrels.

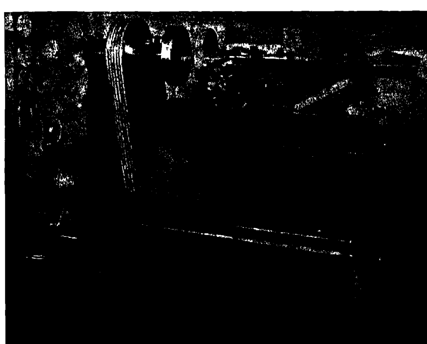


Fig. 239.—Trimming lathe provided with pedal control.

Rolling Mills.—In most cases sheet-metal works receive the material in the form of sheets, strips, foil, circles, and sections, and no rolling is done, but an exception occurs in the operation of mints, which include machinery for reducing the cast bars to size for stamping the coins. Gold, silver, and bronze fillets and strips are thus produced in a state of close accuracy. The rolls are short, and in view of the precision required high-class workmanship is essential, and fine settings have to be ensured in order to bring the strips to the close limits demanded. The speed of rolling varies according to the class of work, but an average is about 80 feet per minute surface speed. An example of the sequence in rolling may be quoted (on a Taylor & Challen mill), with the data as to successive reductions.

The strip is rolled from a bar $3\frac{1}{2}$ inches wide × $\frac{3}{8}$ inch thick, which has been annealed.

First	pass reduces to	·3125	inch	Seventh	pass reduces to	·12	inch
Second	,, ,, ,,	·25	,,	(Anneal)			
(Anneal)				Eigth	,, ,, ,,	·08	,,
Third	,, ,, ,,	·20	,,	(Anneal)			
Fourth	,, ,, ,,	·16	,,	Ninth	,, ,, ,,	·07	,,
(Anneal)				(Anneal)			
Fifth	,, ,, ,,	·14	,,	Tenth	,, ,, ,,	·06	,,
Sixth	,, ,, ,,	·10	,,				
(Anneal)							

The annealing is done at a dull red for bronze (about 1,000° F.) followed by quick cooling in water.

A breaking-down mill for gold, silver, or bronze bars is built with rolls of 12 or 14 inches diameter; in the first size the length is 14 inches, in the other 16 inches, and the revolutions per minute respectively are 47 and 40. A 20-h.p. motor drives the mill through spur and helical gearing. The rolls are made of chilled iron, turned, lapped, and polished, the top roll being suspended by bolts and balanced with volute springs. A handwheel, worm, and screw adjustment may be regulated to a scale reading to ·0005 inch. The rolls can be taken out without disturbing the housings. The feed and delivery table extensions are removable. The method of carrying the pinions is by a cast-iron box, bolted together in the centre, and holding the pinion lubricant, and bronze bearings are fitted in this box. A different mode of adjustment is to be observed in another design, which has a large wedge under each lower roll chock; a duplex bevel gear and screw mechanism alters the height, dials reading to one ten-thousandth of an inch. An adjusting arrangement in yet another example embodies the overhead method, but the twin screws are rotated by bevel gears from a graduated handwheel, thence a pinion turns spur wheels on the screws. One of the spur wheels has a slip adjustment by means of which, on loosening four nuts, the screw can be slightly revolved to set the roll exactly parallel.

A spring balancing device is provided in some instances, so that the top roll and bearings do not drop between passes. Another special

arrangement consists of a cooling outfit whereby a current of water is sent through the rolls. Hardened-steel rolls are provided in many cases. A special-purpose light rolling mill having 12-inch rolls is designed for pinching and flattening copper strips previously twisted, at a speed of 150 feet per minute. The strip passes along a grooved guide; one roll is recessed, the other has a projecting collar.

A larger class of mill is utilised for breaking down and finishing the metal for cartridges and some other kinds of stampings. Slabs and ingots are thus reduced, from sections measuring 3 inches thick or less and about 21 inches wide. The rolls for this service range from 24 to 30 inches diameter, making 5 revolutions per minute, and the larger mills require 250 h.p. to drive.

Drag Benches.—Reverting to mint machinery, mention may be made of the drag bench, which is used for accurately sizing gold and silver strips after rolling. The drag head is fitted with stationary hardened and tempered steel cylinders, the space between which may be adjusted to one ten-thousandth of an inch. The drag jaws release automatically at the end of the stroke, which occurs at the rate of 300 inches per minute. A short portion of the end of the strip has to be flattened down before putting it into the machine, and this is effected on a flatting mill. The lower roll has three flats, which allow the end of the strip to enter between the rolls. As the rolls revolve continuously the strip returns towards the operator, the end being rolled down between the circular parts of the rolls. A grease mill is another adjunct, having a pair of metal rollers, and a pair of felt rollers saturated with oil from a box. Both sides of the strip are thus greased before the strip goes to the drag bench.

CHAPTER 12

DIES USED IN PRESSES

DIES are used so extensively in modern practice for the production of such a great variety of sheet-metal parts, that a study of their design and manufacture becomes a subject of great importance to anyone at present associated with engineering production methods, or others contemplating it. In the foregoing chapters the construction and design of a few of the ever-increasing forms of press tool in use in the factory has been dealt with. In the design of dies and the methods employed in their fabrication, future procedure must be, to a great extent, governed by past experience or upon a knowledge of those methods of production which have already proved satisfactory. Experimenting is a very costly affair, so that the present or future designer or maker of tools can often avoid useless work by studying the practical knowledge underlying the design of existing types, especially when such knowledge has already been tested in commercial production. This information is here given in a brief and concise manner, and the principle underlying a good many tools and dies which actually do the job at the present day are explained.

The many and varied types of die used in a power press for the fabrication of sheet-metal parts can be divided into a very few classes, although a great deal of variety may be found among the units which constitute a general group In the first class may be placed blanking dies, which crop, shear, or blank flat pieces from the material as a primary process to the manufacture. In the next class are those dies which change the form and shape, either by forming, drawing, bending, etc., from the original flat sheet, these being termed forming dies. In the remaining classes are those dies used for bending, forming, and drawing, which incorporate two or more operations, but in which definite classification is uncertain. Those which are the most usual for general or standard uses are piercing and blanking dies in which, as the name implies, the action is to pierce holes in the part to be produced, also to cut or blank the piece out to the required shape ; blanking and forming dies, which sever the piece from the flat and form it to the predetermined shape in two or more continuous operations ; blanking and bending dies, in which the name definitely implies their function ; and blanking and drawing dies which also could not be misinterpreted. These include the main standardised production tools, but there are also the smaller types such as "follow dies," which imply a sequence of operations "following on" in continuation and producing the complete part. With piercing dies, cropping dies, swaging

dies, embossing dies, coining dies, the name explains exactly the job of work which they are expected to do, while staking dies are employed to fix one part on to another by various methods.

The term " die " in the trade usually means the complete tool, but, on the other hand, it can be confined to the female or lower member as distinguishing it from the punch, which is often called the " top tool," which position it usually occupies, although this is not invariably the case. A punch is that part of a press tool which enters into a hole, recess, or opening in the die member. It is possible for a complete tool to be so constructed that one component acts the dual parts of both punch and die, as in a compound tool (see Figs. 261 to 263, pp. 234 to 236); on the other hand, the punch can occupy the lower position if the tool is of inverted design. Should it be that the upper and lower forces perform an identical action, as in an embossing tool, then usually the top or moving member would be called the punch and the other the die. The terms "double-action" die, " triple-action " die, and " multiple-action " die are very misleading, as this signifies the type of press in which the tool is to be used, as, for example, a " triple-action " tool, in a single-action press, could not perform the required number of operations; on the other hand, a single-action tool may perform quite a number of functions, for example, the number which will produce the complete article called for.

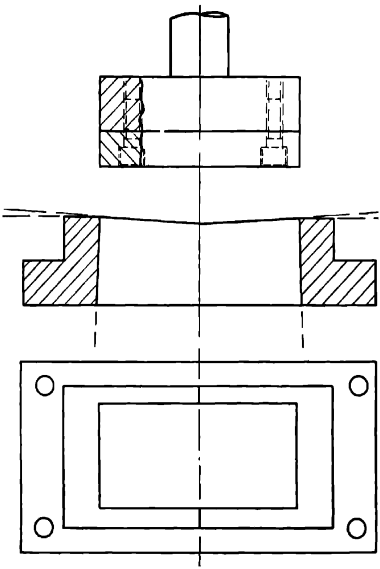


Fig. 240.—Showing die constructed with a shear.

Blanking Dies.—The ordinary blanking die is among the simplest forms of press tool, and its function is to cut out plain pieces of flat material with a definite shape profile. This type of tool is made up of a die, which can be constructed of one or several parts, with an opening which conforms to the shape of the part to be produced or blanked out. The punch, which is in form and size exactly the same as the die opening

excepting for certain allowances, termed "die clearances," which will be explained later. The tool, when operated by a press, cuts or punches a piece, which will be a facsimile of the die opening, from the material placed between the punch and the die. It often happens that the stock to be blanked is so thin that it has a tendency to be driven down between the upper and lower members of the tool concerned, tearing instead of cutting. The area of die opening also having a great effect, the designer must consider this in his calculations, and instruct the die makers to form a "shear" on the die face, by making it lower in the middle than at either end, to reproduce the action as in a pair of scissors (Fig. 240).

Shear on Punch.—This method is only adopted when it is not the blank but the part of the stock surrounding it that is required, and it can be easily visualised that the material resting on the flat surface will remain flat, while that resting on the modulated face will be distorted (Fig. 241).

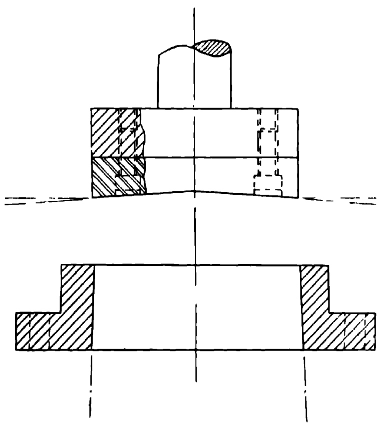


Fig. 241 —Showing punch constructed with a shear.

Stripper Plate.—This part of the tool is to strip the material from the punch which it passes through. In some instances it is made a "snug" slide fit on the punch, which will then act as a guide when the tool is working, but on the other hand, when the tool is of the pillar type, which will be explained later, this is unnecessary, and the stripper can be a slack fit, the pillars maintaining the alignment of the punch and die.

Between the stripper plate and the die face there are placed strips of mild steel, termed "stock guides," which form a channel or road for the material to pass along, keeping it in a position fairly equally distributed over the die opening. This opening is arranged so that the stock can slide through with ease, as there is sometimes expansion when the punch pierces it. Often this channel is formed by a groove being machined in the underside of the stripper plate, in depth equal to the height of the stop, plus the thickness of material being cut up, plus the clearance, which should be considerable in case the strip distorts when struck by the punch. In a tool of this type, the spacing of the holes is determined by stops, will be seen later. It often happens that the shape of the piece

to be punched out is of such form that if a consecutive run is made it would be wasteful of material; in this case the tool is so designed as to make a run, missing every alternate blank, the stock strip being then turned round and run through the other way, or two punches set the reverse way to each other may be employed, which answers the same purpose, although with twin or gang punches they are not always placed side by side in the position in which they will eventually appear on the strip, as the wall between the two or more die openings might be too thin, and would probably break away (Fig. 242).

Before making the die of a blanking tool, it is necessary to discover what size of flat blank will be required in order to form the component when it is bent or drawn up. If it were possible to form or bend metal without thinning, stretching, or ironing, the development would be simplified, as it could be determined with a great degree of accuracy by calculating the area of the finished part, and making the area of the blank to correspond. In some cases there is only a small amount of stretch and ironing, especially if the fabrication can be drawn or formed in one operation, but where several operations are necessary to produce the required shape, there is much thinning of the metal and the blank will have to be considerably smaller in relation to the finished size.

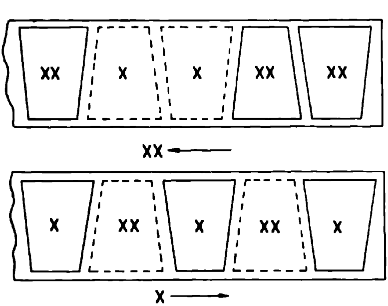


Fig 242.—Two methods of blanking strip.

It is also obvious that the class of metal to be shaped will play an important part; should it be of a soft nature, such as aluminium or copper, the amount of stretching will be greater than if the article is composed of a metal like hard brass or stainless steel.

The pressures required for blanking or shearing are very difficult to determine, as the temper of the metal concerned will have a considerable effect. The following table, based on the shearing strength of mild steel, 50,000 lb. per square inch, carbon steel, 75,000 lb. per square inch, and brass, 35,000 lb. per square inch, may be of interest, but the values given are, of course, only approximate.

Stripping.—No set rule can be used to much advantage in estimating the amount of spring pressure needed for stripping when designing a press tool.

Experience of tool-making, both in this country and abroad, has shown the writer that the potential value of springs is always over-rated by the novice and the amateur, and it is desirable to avoid this failing. Springs

No. of Gauge American Standard, Brown and Sharp	Punching, in lb. 1-inch Diameter Hole.			Shearing, in lb. 1-inch length.		
	Mild Steel	Carbon Steel	Brass.	Mild Steel.	Carbon Steel	Brass
20 = ·031 inch	5,890	8,835	4,123	1,875	2,812	1,312
18 = ·040 ,,	7,854	11,781	5,498	2,500	3,750	1,750
16 = ·050 ,,	9,817	14,726	6,872	3,125	4,687	2,187
13 = ·071 ,,	14,765	22,148	10,335	4,700	7,050	3,295
11 = ·090 ,,	19,635	29,452	13,744	6,250	9,375	4,375
$\frac{3}{16}$ inch	29,452	44,178	20,616	9,375	14,062	6,562
$\frac{1}{4}$,,	39,270	58,905	27,489	12,500	18,750	8,750
$\frac{5}{16}$,,	49,087	73,631	34,361	15,625	23,437	10,935
$\frac{3}{8}$,,	58,905	88,357	41,233	18,750	28,125	13,125
$\frac{1}{2}$,,	78,540	117,810	54,978	25,000	37,500	17,500
$\frac{3}{4}$,,	117,810	176,715	82,467	37,500	56,250	26,250
1 ,,	157,081	235,620	109,956	50,000	75,000	35,000

These figures are for a die and punch without shear

are very valuable in the construction of some drawing and forming tools, for lessening the abrupt shock of the blow when the press is operated, but it should be recognised that the amount of spring pressure needed to push a component out of a die depends on various factors, such as the gauge of material being used, the thickness of the metal conforming to that for which the tool was designed, and the shape of the component being stripped. Thus, if a tool were designed and made to strip material ·032 in thickness and the stock happened to be ·036, in all probability it would stick or there would be difficulty in pushing it off. The amount of power needed to strip the metal from a punch which has passed through it is governed by area, and also the thickness of the metal or other substance being cut up. As a practical example of this, if it takes 100 lb. pressure to strip material ·032 inch thickness from a punch 1 inch in diameter, then it will require 200 lb. to strip the same material from a punch twice the size. On the other hand, if the thickness of the material being pierced is increased from ·032 inch to ·064 inch, exactly the same proportional increase in power needed would apply. Furthermore, should the blank being struck have any large piercing previously, it will require very little effort to force it out of the die, as when it is struck by the blanking punch it will have a tendency to collapse on the hole, which in some tools causes a great deal of trouble, as will be explained later.

Medium-size Blanking Tools.—The process of manufacture differs with different sizes of tools, again tending to show that no set rule can be adhered to. A few years ago, very few tool-makers agreed as to method of procedure, many being convinced that the punch should be made first, whilst others were equally certain that the die should have precedence. The writer, having studied the question quite deeply, has come to the conclusion that the simplest way is to make the punch and then make a die to conform to it, although by this method the blank

produced can very seldom be guaranteed to size to within a few thousandths. Should it be necessary that the blank produced must conform to a definite size, known in the tool-room as " spot on," or to come within a tolerance error of ·002 inch, then the die requires to be made first.

A definite line should be pursued with regard to the making-up of a good-class blanking tool, and if it is done in the stages which many years of experience have shown to be correct, not much can go wrong; but without a system anything may happen.

The making of an ordinary medium-size blanking tool in an ordinary shop may be first considered, and if it is assumed that there are no expensive and elaborate machines such as are on the market to-day, the tool-maker's knowledge, craftsmanship, and initiative will be relied upon to carry the job through. The drawing, if one is available, should first be studied and the form marked out on metal—a piece of brass or steel—as a template. The necessity of checking over the dimensions several times may be stressed in order to be quite sure that the template is really correct, as, to discover that something is wrong when half-way through the making of the die is a catastrophe indeed. In several small shops the template is checked over by an inspector before the tool-maker proceeds.

Assuming now that the template is correct, a piece of steel is prepared for the die and a piece of mild steel for the stripper plate, both being of about the same size, although the die is usually the thicker of the two. Hot-rolled or " black " mild steel is the best to use, as cold-rolled or bright mild steel (which is the same thing) retains the stress imposed by the rolling and when the centre piece is cut out it is liable to distort. Should it be necessary to use cold-rolled steel, then it must first be annealed by heating it up to a dull red heat—700° C. (approx.)—and allowed to cool off. These two plates are then screwed together, after having the faces ground, if this is possible. Four screws and four dowels are usually employed, and they should be so arranged as to pass through the stock-guide strips and not interfere with the die opening (Fig. 243.) A corner of each plate is usually marked with the centre punch to facilitate assembly and the two plates are taken apart.

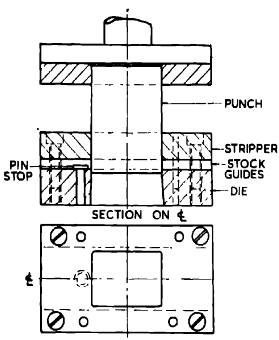


Fig. 243.—Example of a small blanking tool

It now behoves the tool-maker to concentrate on the die, as this is the all-important part. The face is washed over with sulphate of copper (or " bluestone ") and the die marked out, preferably with the height gauge. The cutting-out process before the advent of the band saw was always accomplished by drilling a series of holes as close up to the profile

line as possible, but that part of the profile which followed any radii was always drilled and reamered to size. The question may be asked, "How is it possible to get the various radii to size if they do not conform to standard?" The method employed for this by the experienced mechanic is quite simple. He chooses drills as near to the radii size as possible but ·015 inch smaller and then employs tapered reamers, which he uses from the back of the die, until the exact size is gained at the face, at the same time producing the necessary angle for die draught or backing off, which can be followed right round the die opening (Fig. 244).

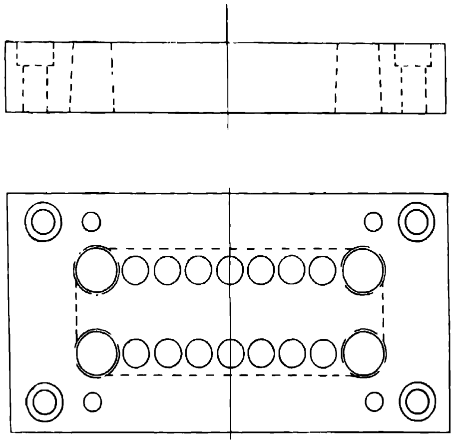


Fig 244 —A die face—holes following radii

Improvised taper reamers are not very difficult to make, should such an emergency arise. Silver steel or any form of low-grade carbon steel is chosen of the nearest size to the larger end of the reamer needed; it is then turned to the required taper, which, in this case, would be ½°. Six fairly equal sides are filed to form six edges and a square is made at the top end to fit a wrench. The reamer is then hardened and tempered. When these holes have been made to satisfaction, the remaining holes are drilled to remove the centre, which will eventually form the die opening.

DIE FILING BY HAND

To the great majority of inexperienced people, filing merely means the backward and forward motion of a file, thereby causing a certain amount of the material to be removed. To the tool-maker it is quite a different matter; it is an art by which the good mechanic signifies, not necessarily the amount of time he has devoted to the job, but the amount of real effort he has put into it to bring his work to a state of perfection. In the technical branch of any of the fighting Services, the qualifying trade test for a fitter mechanic is a filing job, and it is generally agreed that this is the best method by which a fitter can be judged.

To the improver, apprentice, or others whose experience and knowledge in this direction are limited it may be mentioned that with the ordinary back-and-forward motion of a file one cannot under any circumstances produce a flat surface. No matter how practised the operator may be, there will occur a certain amount of roll. This can be quite easily proved by putting a straight-edge on the face which has been filed and holding it up to the light, although most probably the contour of the surface can be felt by simply rocking a steel rule upon it. The correct method of finishing a piece of steel if a flat surface is required is to scrape the high spots off, having first rubbed it on the surface plate or any flat surface which has been previously coloured with Prussian blue or other suitable material to mark it. When one is satisfied with the flatness, take a fairly large, smooth file and, holding the handle in one hand and resting the other end of the file on the job, make a small circular motion, taking pressure on the file with the fingers of the other hand. Not, of course, keeping it in any one spot, but moving it gradually about on the surface until it is covered with a series of circular scratches. A little paraffin during this operation helps, and when the surface has been afterwards wiped clean and a coating of oil applied, it looks rather attractive, or at least "finished."

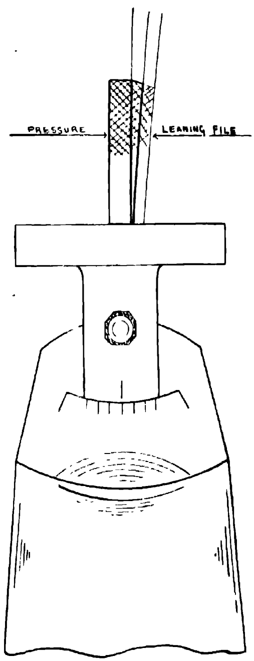


Fig. 245 — Bench filing machine, showing possible error.

The filing machine is one of the greatest inventions to minimise inefficiency in a tool-room, and it is also wonderfully effective and rapid when producing a die, but if such a machine is not available, all small dies will have to be finished by hand. Many tool-rooms that produce small high-class tools provide rapid-moving bench filing machines which, if used with care, will produce any desired flat surface; there is, however, one great drawback to this class of machine which has to be noted and avoided. Owing to the fact that the top of the file is totally unsupported, when the part to be filed is pushed up against it, the file naturally leans outwards, removing much more metal at the bottom than at the top, and probably instead of $\frac{1}{2}°$ that the die required, it may be discovered that the taper is about 5°, which makes a die practically useless (Fig. 245).

The usual amount of taper or draught on a die is from $\frac{1}{2}°$ to $1°$; any greater angle than this lessens the life of the blanking die, owing to the fact that the dies have to be continually ground to recover the edge worn by previous use. Owing to this necessary angle, or "backing off," the more that is ground off the die face the larger the die opening becomes, until eventually there is too much clearance between the punch and die for the tool to be effective, as the part that is produced will have a large burr. Hence, the lesser the amount of angle the longer the life of the die.

The question may be asked, "Why not have the die parallel?" This, however, is impossible, since in an ordinary follow-through die, when the punch strikes it causes the metal to expand; other blanks follow, one on top of the other, and by their pressure expansion is also taking place until —before they can reach the bottom and be expelled the die will burst. Disregarding the thickness of the stock which is being cut up, necessitating some clearance between the punch and die, the blank conforms to the shape and size of the die. When it is considered that $\frac{1}{2}°$ is about ·009 to 1 inch, the necessity for the inside edges of a die to be filed perfectly flat will be readily understood; it would be useless if a bump only ·005 inch high projected for a distance of, say, $\frac{1}{2}$ inch down.

Before filing machines were invented, all precision filing had to be done by hand, and the new bench mechanic may be advised to do his utmost to reproduce the high-class work accomplished by the older type of skilled craftsman. It is unfortunate that the apprentice of to-day is taught so very little hand filing, as it is an art that is very necessary if one is to become a competent bench fitter or tool-maker.

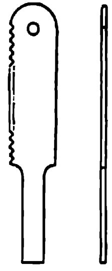


Fig. 246.—Cutter made from machine saw blade.

The mechanic who is going to make a die by hand adopts in almost every case the same principle. After the holes have been drilled as close up to the profile line as possible and about $\frac{1}{4}$ inch diameter, and the radius of one hole almost reaches the radius of its neighbour, the wall is broken away with a tool which is made from an old machine hacksaw blade, a chisel in this case being useless, unless it is to chip away some of the "burrs" after the piece in the centre of the die has been removed (Fig. 246). Rough files are to be preferred for any metal except brass, as when these are used the amount of cut can always be governed by the pressure applied. Moreover, they do not corrode so easily. Oil is the greatest enemy to filing, especially carbon steel; it is, therefore, very advisable to keep the job clean. Even to place one's finger on a job that is being filed, trying it for smoothness, is very wrong, as the touch leaves a film of grease, which the file has to pierce before coming into contact with the metal again. It is merely a habit—by which one can usually discern the novice. Short files are better than long ones for this particular work, as it is obvious that they do not roll so much, the amount of leverage being less. The good mechanic is continually checking the

surface being filed, with the square and straight-edge, as appearances may be very deceiving. It is possible to obtain, from good precision tool-makers, gauges 89° 30′, which are extremely useful in blanking die work, and one of these is shown in Fig. 247. Good hand filing is a tedious job, as it cannot be done quickly, and if there is any danger it is advisable to remove the corners of the file by grinding.

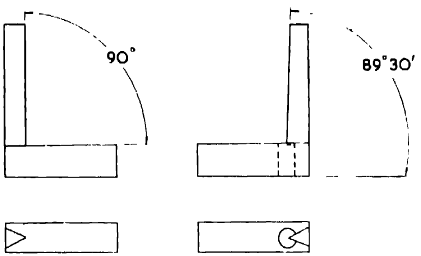


Fig. 247 —Gauge for checking die draught

The filing is continued and the template worked in from the back, as, owing to the taper, this is the larger end. Two-thousandths of an inch (·002 inch) appears a very large gap when the job is held up to the light, and this is the time when the tool-maker takes notice and just removes a little from one side, or a little from one corner as required, entering the template again and again for inspection, until it is gradually worked in. The finishing touches are usually given with Swiss needle files, as, by the very fact that these files are flexible, it is made possible to produce a flat surface or reduce a definite spot (Fig. 248). Assuming now that the template is a nice slide fit in the die and can be pushed right through with a little effort, the line of procedure is to have the die hardened and tempered, and after the hole has been cleaned out with a carborundum stone and paraffin, it is usually rough surface ground.

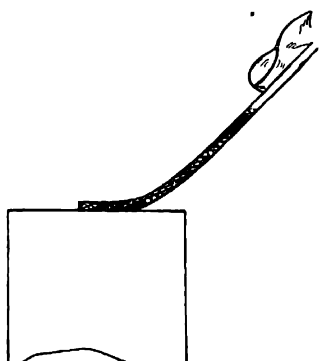


Fig 248 —Needle file in operation

The Punch.—This is generally made up from the same material as the die, although in some very large factories where they manufacture their own tool steel, separate material is supplied for each part. For a punch of this description there are several methods of making, and also of fixing. After having been reduced down to something near the size required, one end is set out in the same manner as the die was, but when it is machined down about ·002 inch is left all round the line, which allows

for shearing. This punch is now placed on top of the hardened die and after it is ascertained that the whole of the die opening is covered it is given a " bump " under a fly press. By this action the punch will be driven into the die about ·010 inch and given a definite mark to work to. The file now comes into operation again and the surplus metal is gradually removed. The punch is placed back again on the die face and given another bump, and so on, until it has been worked right through the die. Care must always be taken that the punch goes down perfectly perpendicular, and for this reason the tool-maker works with the precision square (Fig. 249). Now that the punch is a slide fit in the die, dependent upon the gauge of the material that is going to be blanked out, it can be reduced for die clearance, as the blank will conform to the size of the die opening.

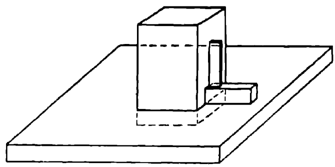


Fig 249—Keeping the punch perpendicular

Punch Mounting and Fixing.—There are several methods of fixing the punch to the punch plate which carries the spigot for entering in the press ram. One is to screw the punch on to the plate and then screw the top plate on to that. The oldest method, and the one usually employed in the case of small- and medium-sized blanking tools, is to cut an opening in one plate through which the punch passes with a tight fitting, the top end being previously burred over with the hammer and the plate recessed to accept it. The other plate or punch pad is screwed on the top to take the pressure when the tool is operated in the press (Fig. 250).

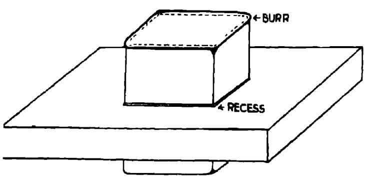


Fig. 250 —Showing method of retaining punch by burr

There is now on the market a machine, called a punch shaper, which does away with separate mountings, and shapes the punch out of the solid, thereby eliminating a great amount of trouble. It is extremely accurate and can reduce the metal down very easily to within a margin of ·002 inch. One of these machines is shown in Fig. 251, the way in which the tool moves when cutting a punch being shown diagrammatically in Fig. 252.

The Stripper Plate.—There are two distinct methods of stripping, one being by the use of a spring stripper, the other by a positive or dormant stripper. The latter is the more frequently used and is preferable whenever it can be conveniently fitted.

The spring stripper has many disadvantages as compared with the dor-

mant stripper ; for example, the spring stripper is attached to the punch and so cannot act as a guide, whereas in the case of a positive stripper it is attached to the die and acts as a punch guide, also absorbing a considerable amount of vibration when the punch strikes. Swiss and German tools are fitted with very thick strippers which are a good slide fit on the punch. The stripper plate having been made, it now requires the neces-

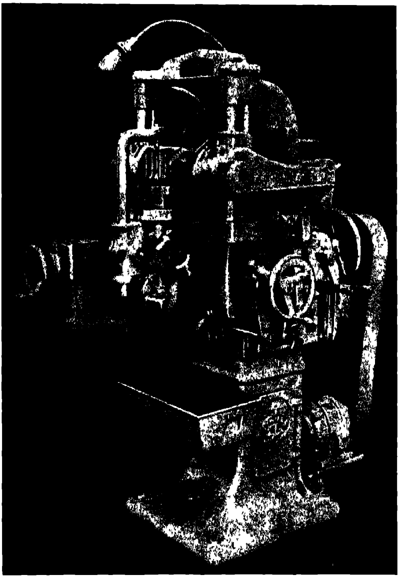


Fig 251.—Illustration of Thiel punch-shaping machine. (By permission of E. H. Jones (Machine Tools), Ltd., London.)

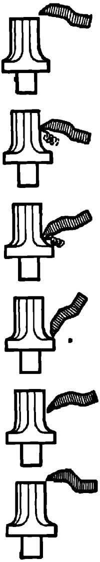


Fig 252 —Showing stages of the action in shaping a punch with a Thiel machine.

sary opening in it. The usual tool-maker's method of procedure is to screw it back on the die and with a thin scriber mark round the die opening, after which the piece is cut out much in the same way as was the die itself. The punch is then pushed up through the die, top foremost, with the stripper plate in position, then filed, and gradually drifted, until it goes right through.

Stock Guides.—These are two parallel strips which separate the die from the stripper plate, and which also act as guides when the stock is being fed into the tool for blanking. They require to be at least four times as thick

as the material for which the tool is designed, as the stock does not remain flat but distorts considerably in the process of blanking out, so that if insufficient room is left the strip of material will be difficult to pass through owing to it jamming. Where an ordinary pin stop is used, the guide strips must also be thick enough to allow the stock to be fed over the stop. In fitting these, they are usually clamped on to the die and the holes transferred through into the strips, just leaving sufficient overlap on each side of the die opening for the minimum amount of waste possible, without cutting it so fine that the strip will break away when being cut up, as the ragged edge will always cause trouble (Fig. 253). Some tool designers insist on one side stock guide being fitted with springs to force the material against the other guide.

Stops.—When strips of material are being fed into a press tool in the operation of blanking out, or drawing up, or pierced, or anything appertaining to the production of an article or component, it is governed by stops; these have to be decisive, quick, and positive. Stops are designed and set to minimise the amount of scrap metal, consistent with good working and to position holes, etc., in dual- or multiple-operation tools. Since press operators are usually paid piece-work rates, the true working of stops on the tool they are using plays a big part in the contents of their pay envelope at the week-end. There are many types of stop used for various mechanical production operations, and those in general use, which may be called standard types, will now be described.

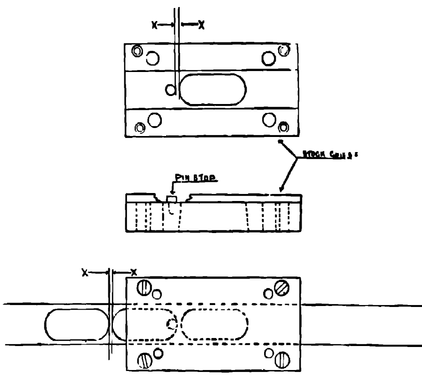


Fig 253.—View of stock guides and pin stop

Pin Stop.—This type is slow in operation but is suitable for large or thick blanks or where only a small quantity is needed at one time. It consists of a pin driven into a small hole in front of the die opening. The strip of material to be blanked out is pushed into the tool until it is obstructed by the stop, when the press is operated and one blank struck. When the punch is on its up stroke, which is the completion of one cycle or stroke of the press, the strip of metal hits on the underside of the stripper plate and the punch continues to move upwards, being withdrawn

from the material which it has passed through; when the punch is wholly withdrawn, the strip will then drop back on to the die face. It will be seen that, if at this moment the metal is pushed forward, instead of dropping down to its former position it will move along until the pin stop enters the hole in the strip which the blanking punch passed through previously, and the material is now in position for the next blank, when the operation is repeated, the distance xx representing the minimum clearance between one hole and the next (Fig. 253).

With this type of stop it is only possible to operate the press one stroke at a time, instead of continuously.

Trigger Stop.—This is the universal stop used in all production shops where quantity is desired. It is very simple in construction, rapid in action, and works just as well on a press doing either sixty or 300 strokes to the minute. Most operators, especially females, when once they acquire the "touch" of a certain stop, which counts for a great deal, can feed strip into a tool with a press doing 200 strokes per minute for an indefinite period with very few failures. This illustrates the confidence gained by the press operator with a good smooth-working stop.

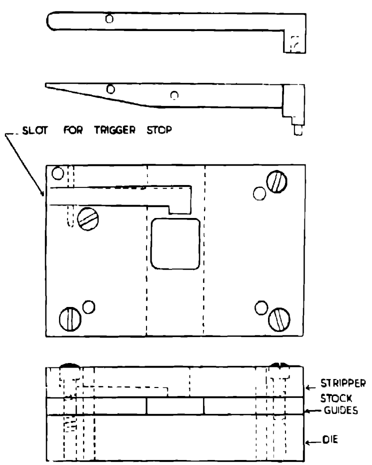


Fig 254 – Construction of slot to accept trigger stop

The trigger is usually made from mild steel case-hardened with cyanide or some other suitable compound to restrict wear, of which, on the stop end, there is necessarily a considerable amount. The spring which operates it is of considerable importance, and should be very lively and of medium tension; too light a spring is liable to cause failure, which usually scraps the whole strip of material; or too heavy a spring throws a great strain on the person operating the tool, which, of course, should be avoided whenever possible. The trigger stop is only very lightly lubricated, since over-oiling causes sticking (Fig. 254).

In Fig. 255 the trigger stop is shown as it is usually constructed, with the slot ready to receive the trigger, the essential clearance being somewhere between ·020 to ·050 inch. With the spring of the required length, it will be observed that it is pulling up that end of the trigger to which it

is connected, thereby forcing the other end down on to the die face; it also has a side pull forcing it up against the front face of the slot in the stripper plate.

When the strip of material is fed into the blanking tool sufficient force is used to push the stop to the back of the trigger slot against the weight of the spring. The press is then operated and one blank struck, and the trip screw is so adjusted that the trigger is just depressed at the end of the stroke, when the other end will move upwards clear of the strip. When the press completes the cycle and withdraws the punch, the stop would normally resume its position on the die face, but owing to the fact

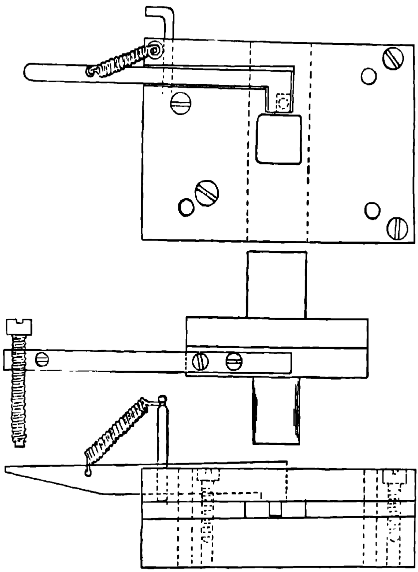


Fig 255.—Trigger stop and trip screw.

that the spring is giving a side pull the stop will come down on to the top of the strip instead. This will then allow the material to go forward by the pressure that is placed upon it by the operator, until the stop drops into the hole struck by the punch, which brings it to a standstill. The process can then be repeated in slow or rapid succession, according to the press being used and the gauge of the material being cut up.

The Finger Stop.—This stop is nearly always used in conjunction

with the trigger stop. If, for instance, one or more holes are pierced in the part to be made by the tool, or a form pierced out before the blank is struck, then the tool must be fitted with a finger stop to govern and position the strip (Fig. 256).

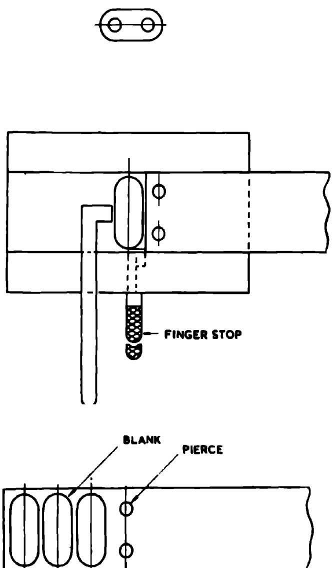


Fig. 256.—Construction of finger stop—pierce and blank.

The material is pushed into the tool up to the finger stop, the press is operated, and the hole or holes pierced. The finger stop is then pulled out and the material strip pushed up to the trigger stop; the press is operated again when the part is struck with the holes in, at the same time piercing the next holes. By this means the two operations are performed at one time, from which this particular class of tool derives its well-known name of "pierce-and-blank" tool.

Heel-and-toe Stop.—The "heel-and-toe" stop is suitable only for tools producing larger-size blanks or work requiring $1\frac{1}{2}$ inches minimum movement between the stamping operation, as the whole of the stop has to be accommodated within the pitch, as may be seen from Fig. 257. Because of the greater distance that the material has to move at each stroke of the press, a relatively slow action is necessary. The heel-and-toe stop is "positive," which means that it is almost impossible to feed the strip more than the required distance either inadvertently or deliberately, which is an extremely useful feature. It is a little more costly to fit than the trigger stop and slightly more difficult to adjust, but for blanks of reasonable material thickness it will give excellent trouble-free service.

The drawing shows a sectional view of the latch construction, die face, and the material in position, the latter being fed to the right. The method usually adopted for fastening the stop to the stripper plate is to have two lugs, either integral or attached to the plate, with the latch working between them on the hinge pin. The small pin A is forced forward by the spring so that the point engages in a depression machined to a like form in the rear part of the latch in such a position that when it is engaged

the forward or stop end of the latch is touching on the die face. It should be noted that the profile of the latch forms part of a circle centred on the pivot point. This is arranged so that the entry or withdrawal of either the heel or toe is possible without movement of the material occurring.

In operation, the material is pushed into the tool until it meets the stop, at which point the press is operated. At the same time, as the punch or punches hit the material the trip screw *B*, which is mounted in the upper part of the tool, comes into contact with the latch and depresses the "heel," causing the "toe" to rise clear of the material. The strip material now moves along until it touches on the underside of the "heel," which is forced up and automatically sends the "toe" down into the opening left by the previous blank, the pin "clicking" into position.

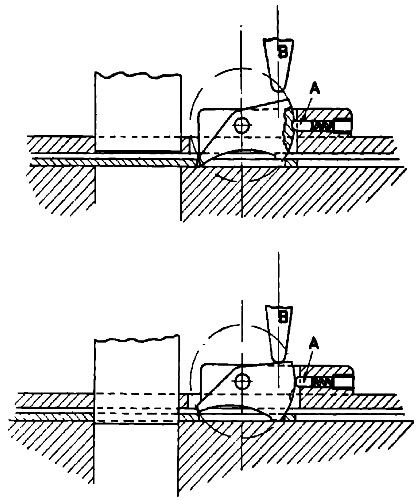


Fig. 257.—The design of a typical heel-and-toe stop.

The positive action is determined by the construction. When the stop is correctly adjusted, only a few thousandths of an inch plus the material thickness is allowed below the "heel" of the latch when the "toe" is in contact with the die face, which makes it practically impossible for the material to move along unless there is an opening into which the "toe" can drop.

When adjusted to the requirements of the strip material with which the tool is to be used, it is essential to harden the latch, as there is considerable friction, and wear occurs at the point, this reducing the positive efficiency of the stop.

Trimmer Stop.—This stop is designed to operate on thin sheet-metal strip, especially in cases where there are no holes that can be utilised for accurately controlling the position. For a "follow-on" tool which is designed to bend or form a part in addition to severing the piece from the material strip, it will be realised that the position has to be positively controlled to obtain uniformity, particularly if any "draw" or stretching

takes place in the production of the piece-part. Some tools are designed with a trigger stop and ancillary pilots to control the strip, and for this purpose special holes are pierced in parts of the material where they are of no consequence, this method being also adopted if the holes in the component are too small for use as a pilot.

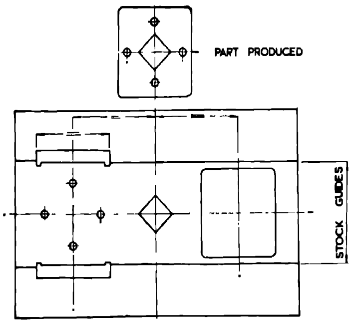


Fig 258. Plan view of a die designed for trimmer stops.

With trimmer stops, however, the usual method is to trim off about $\frac{1}{64}$ inch each side of the strip by progressive steps in order to control the entry of the material into the tool. Stock guides are fitted to these tools to work in conjunction with the trimmer punches. The first part of the passage is wide enough for the strip material to enter, after which there is an abrupt narrowing of this passage by a step protruding on each side by approximately $\frac{1}{64}$ inch. Trimmer punches are fitted in openings in the die so that at each stroke of the press sufficient material is trimmed off to allow a further section to enter. From this it will be seen that the amount of movement for material feed can be controlled to a fine degree.

The trimmer punches are the same length as the blanking punch, about $\frac{1}{4}$ inch thick, and exactly the same width as the pitch of the tool for which they are designed. In order to resist outward pressure, these punches are ground back to form a step at the bottom end so that part of the punch enters the die before it strikes the material. To avoid the formation of projections on the strip between each consecutive trim, the punches are so shaped that a notch is produced instead. This is necessary because obstruction on the edge would be detrimental to the proper working of the tool. The drawing in Fig. 258 shows the plan view of a die designed for trimmer stops. Fig. 259 provides an example of a trimmer punch, and Fig. 260 shows the material strip as it would appear after three strokes of the press.

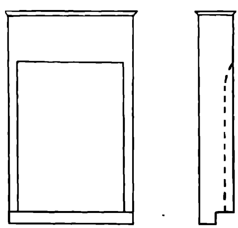


Fig 259 —An example of typical trimmer punch

Opinion differs slightly as to the best type of stop for any particular job, but the following notes provide a useful guide : use a plain pin stop for small quantities of parts which can be produced on a fly press or

machine press with an interval between each stroke, and for fairly small blanks, with or without holes, where the material thickness is $\frac{1}{32}$ inch or more, the trigger stop is often the best. For blanks over $1\frac{1}{2}$ inches in size use a heel-and-toe stop, whilst for precision piece-parts from thin material, especially with tools of the "follow on" variety, the trimmer stop is generally the most suitable type.

Press Tool Pilots.—When designing press tools the pilots are often treated with secondary consideration, instead of which they should be deemed as of primary importance and given the same careful thought as when designing the tool. Pilots are both the direct and indirect cause of a large percentage of the minor breakdowns on high-production press work where the tools are small and of two or more stages. For this reason the following hints are useful: pilots should always be made from high-grade material and, if possible, from high-speed steel. They must be hardened and polished, and when allowing for clearance, consideration should be given to the fact that a pierced hole closes in slightly when the punch is withdrawn. Pilots should not be less in diameter than one and a half times the thickness of material being worked in the tool.

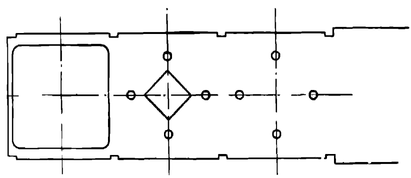


Fig. 260.—Showing the strip of material as it would appear after three strokes of the press.

Blanking and Drawing Dies.—There are many types of tool capable of doing both of these jobs at one blow. The tool which appears to be most efficient and possessing the longest life, although rather costly to produce, is known as a "pillar-type" compound tool.

In the design of a press tool, much consideration must be given to the quantities required as well as to retaining the shape and size of the article. For example, those firms that supply telephone components are held down to such close limits and such enormous quantities are required that efficient tool life is a most important factor; consequently, the majority of these firms specialise in compound tools, which ensures a parallel die.

In other trades it may be different; for example, aircraft makers, owing to continuous experimenting and the resulting modification, often make some of the crudest forms of tool. Other firms which specialise in the manufacture of the small fittings, of the type purchasable at the multiple stores, use mostly follow-on tools, as quantity is the only consideration, a few burrs and the holes getting a trifle larger being of not much consequence.

From time to time large companies, particularly those who make a very

close study of the factors which affect the cost of production, alter their tool design, although in the last few years British firms have adopted the principle of a series of operations, as being preferable to doing the job all at one blow or on the follow-on principle, which can be regarded as the German and Japanese methods.

It will be easily gathered from the foregoing explanation what is the meaning of "tooling costs," and it will be realised that it is not so much the price of a tool that matters, but the cost of the article it produces, and this is entirely governed by quantity.

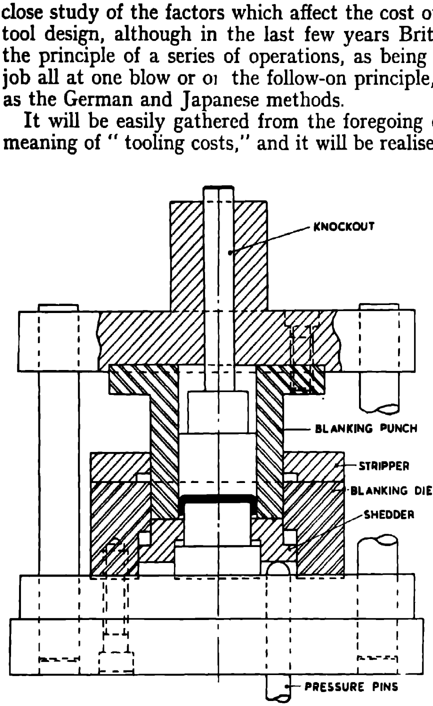


Fig. 261.—Compound tool—forming cup.

Compound Tools.—As already mentioned, this type of tool is constructed with a parallel die, or, in other words, there is no die draught or "backing off." The piece part is ejected from the top of the die, which makes any angle quite unnecessary. The tool can be ground over and over again without any alteration in the size or shape of the component it produces. The die is situated at the top of the tool instead of the bottom as in the majority of cases. It descends down on to the punch, which is a fixture on to the bottom bolster (Fig. 261).

The determination of the size of the blank in a compound tool to produce articles by blanking and forming may require careful consideration and possibly a certain amount of experimenting will be necessary. The size of the blank needed can in many instances be fairly accurately gauged by the weight. As an example of this, a sample of the component needed is made up either by temporary tools or, if of circular form, by being spun on a former in the lathe and afterwards trimmed or turned down to the exact size. The sample is now very carefully weighed on a sensitive scale, and then, knowing the weight of sheet metal per square inch, the diameter of a piece can be computed which will be equal

in weight to the sample. Should there be a trimming operation after drawing, then a small percentage is added to allow for this.

Blanking and Perforating Dies.—The terms "pierce and blank," and "blank and perforate," really mean exactly the same, in some localities the word "perforate" being used while in others the word "pierce" is preferred. It might be suggested that "blank and perforate" should apply to a tool which does the two jobs simultaneously, and, on the other hand, the tool which has to pierce the holes before blanking, although the operation is progressive and continuous, could be considered as a pierce and blank.

For blank and perforate the compound tool is ideal, as the accurate positioning of holes so necessary in high-class work, such as telephones, electric meters, etc., can be easily effected. Fig. 262 is a sketch of a tool used in this type of work showing the various details (Fig. 263), and the stripper plate (Fig. 264), so that the process can be clearly visualised. This type of tool is used extensively in the production of small high-class electrical fittings in nickel, brass, fibre, etc. It is not very rapid in action, and sometimes requires a compressed-air pipe attached to the press to keep it clear of waste pieces of material. When blanking, the stamped parts nearly always return to the strip, but this difficulty is easily overcome by having a little spring pin projecting above the blanking punch which will then throw them off. The die and punch being quite parallel, they can be ground over and over again, and if the perforating holes are very slightly "backed off," say by about one-quarter of a degree (15′) (which is sufficient if accurate), the component will retain its shape and size without the slightest variation even after the tool has produced millions of stampings.

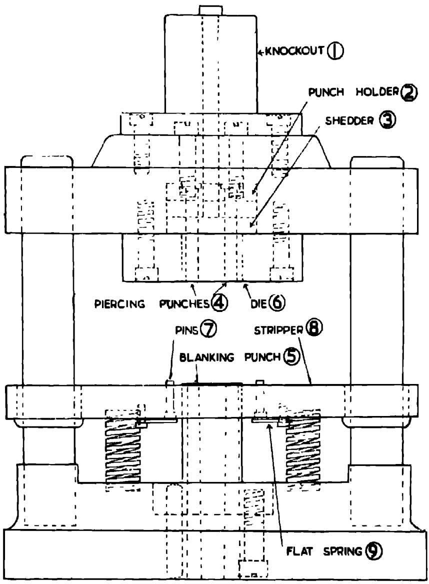


Fig 262.—Compound tool—blank and perforate

Perforating Sheet.—Some types of perforating presses for working on flat material are designed to perforate the entire width at each cycle of the press. The job is fed in with various types of mechanism, such as "roller" or "gripper" feed, and moves forward after each stroke mechanically. The holes are usually perforated two rows at a time, the first set being at an angle to the second. Some presses are designed to do this hole-staggering by a mechanical device, shifting the sheet from one side to the other, in which case only one row of punches is used. For perforating heavy sheets, where one design only is needed, the guides which locate the material are made movable, so that perhaps ten to twenty holes or patterns can be pierced and then the sheet moved over and another series punched. There is another design of press, in use where a firm specialises in this class of work, which by modifying the feeding does away with the necessity for more elaborate and larger dies. This is termed the "interrupted feed," and is so arranged that the material can be fed in by irregular movements. The economical advantage of this will be at once realised, as, for instance, if the perforations were equally spaced they could be pierced with the aid of an ordinary trigger stop, but being unequally spaced, if this special mechanism was not available the die would have to be designed to produce the staggered or irregular spacing.

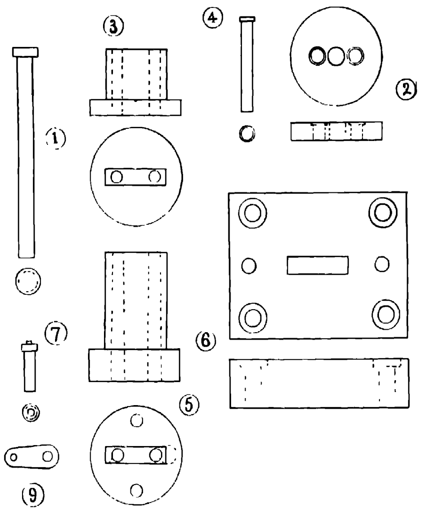


Fig 263.—Details for a compound tool

Perforating Cylinders.—The tools used for perforating the sides of cylinders are very similar to blanking tools, excepting for certain alterations in the design to conform to the circular surface, instead of working on the flat. Taking as an example a shallow shell with twelve piercings round the rim, this would be done with a single punch, but the arbor to which the component is temporarily fixed would revolve on a spindle, by an automatic cam action, operated by the press. When the desired number of perforations had been made, the press would be

thrown out of action, also by a cam, to enable the component to be removed. Up to a few years ago, a big trade was done in the fabrication of oil-lamp and gas-burner galleries (Fig. 265), which, owing to their technical needs such as the inlet of air for consumption, and the springiness of the tags to hold the glass chimney, offered a great field for ornamental perforation, and many were the inventions and mechanical devices adopted in the process of fabrication. One great advantage was prominent in the construction of these galleries: they had to be made from very hard brass, and this makes for a clean hole in piercing. The hardness of the brass was produced by burnishing, or by imposing a hardening draw just before perforating.

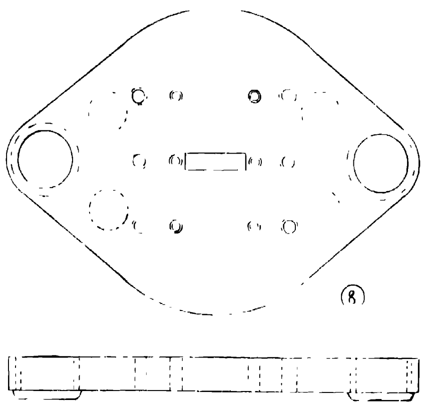


Fig 264 —Compound tool—the stripper plate

It is not to be supposed that these automatic, revolving, perforating tools are in general use through the country; indeed, that is not so, and many small factories turning out good clean articles produce them with dies of the simplest nature in fly presses. Many small shops do not use presses at all for this class of work, but a device which is fastened down on a bench, and provided with a fairly long handle which operates the punch-holder (Fig. 266). The first ornamental clipping on the gallery becomes the location which " picks up " on a pin, one piercing is made, then the component is moved round, and so on, until completed.

Soft-steel Dies.—In the majority of cases with high-class tools, the dies for these would be made from best-quality cast steel, hardened and tempered, but it will be understood that owing to the fantastic shape, these dies are very costly to produce, and also, owing to the fabrication being composed of very thin metal, the amount of die clearance must be minute, otherwise a burr will result, which in ornamental piercing of a finished article is entirely out of the question. The method adopted in many small shops where elaborate design in piercings are required is to make these dies of high-speed steel, but leaving them soft. It is very surprising, to those unacquainted with such matters, to note the length of time that these tools will stand up before the component begins to show a burr.

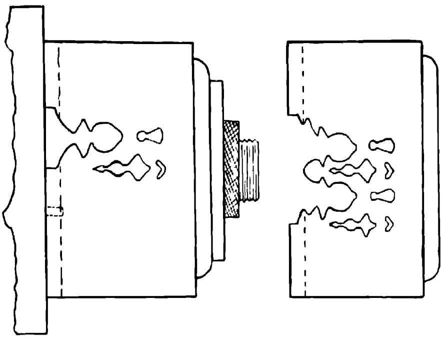


Fig 265.—Piercing a lamp gallery

When this does occur, the die is sometimes gently "tapped in" with a small hammer, or even forced in by rubbing a burnisher over it and then just shearing the punch through again.

Stripping.—This is a very important part of the operation where ornamental piercings are concerned, and must in all cases conform to the outer radius of the article being pierced. It is usual to have small strippers backed up by springs, as, if ordinary stripper plates were used, especially in the case of the lamp galleries, the tabs would have a tendency to lift and distort. The strippers are made a nice slide fit on the punches, and in the case where more than one are needed, each has a steadying effect on the other. Where rubber is substituted for springs, it is advisable to have laminations of soft rubber, similar to that which a motor-tyre inner tube is made of, in preference to a hard block.

Triple- and Multiple-action Dies.—Triple- and multiple-action dies, as the term signifies, implies the adoption of three or more distinct operations in conjunction with each other to produce a component with one cycle of the press, such as, in triple action: blanking—drawing—stamping; or in a multiple action: blanking—drawing—embossing—piercing.

This type of tool is preferred in some engineering factories where cutting the cost of production is a feature of the business; as the action is rapid the process is continuous and the formed part delivered at the bottom and not at the top as in most forming tools. An inclined press is used and the pieces slide back by gravity, usually into boxes, and are thus ready to be carried away. In the operation of the die, the blank is cut by the punch, which continues its pressure while the cup is

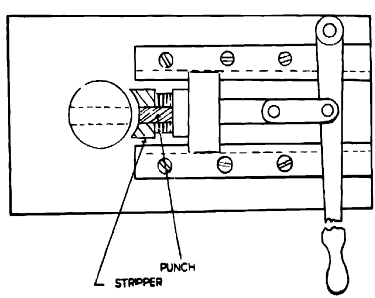


Fig. 266.—A bench fixture used for piercing.

drawn by the central forming punch. The piece part is then carried downwards until it engages the stamping or embossing die, which is mounted on a separate ram and performs its individual operations on the upward stroke. This can be fancy embossing, lettering, etc. On the upward stroke the component is stripped from the forming punch and falls away on its own accord. This type of tool (Fig. 267) is used mostly for can lids which require lettering, or fancy tops for packing jars, also seamless tins used as containers for fish paste, etc.

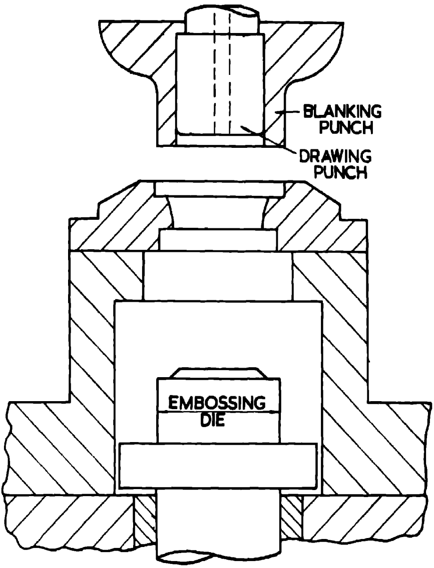


Fig. 267.—Example of triple-action die. Blanking—drawing—embossing

GENERAL DATA

Die Clearance.—It is impossible to enter a 1·000-inch diameter plug into a 1·000-inch diameter hole ; to do so either the plug must be minus or the hole plus ·0002 inch, this clearance figure varying according to the diameter. In the case of dies the clearance is increased slightly in order to assist in cutting the metal and to avoid straining the die by driving slugs into it and so causing additional stress by expansion. Over a period of time a formula has been built up expressing the amount of clearance desirable, and if these figures are adhered to a good clean job can be obtained without causing additional strain on the press above the actual pressure needed to stamp out the part.

When the inspector examines a press tool, particular attention is paid to the part produced from it on the try-out press, *i.e.* before the tool is actually taken into use for production. If it shows a burr, the die clearance is excessive, whilst if the blank is " bright " round the edge as if it had been forced through the opening, or shows bright polished spots, then the clearance is insufficient. The edge of a well-cut blank should be

consistent all the way round, one-third of the top portion of the edge having the distinct appearance of having been cut, and the remainder showing a clean fracture.

When calculating clearance the constant for various classes of sheet is given as : mild steel = 16, hard brass = 18, soft brass = 20, light alloy = 20, and copper = 20. To obtain the die clearance, the thickness of metal to be cut is divided by the constant, thus :

$$\frac{\text{Thickness of metal (in.)}}{\text{Constant}} \quad \text{Clearance (in.)}$$

In the case of parts to be produced from ·030-inch thick mild steel, would be :

$$\frac{\cdot 030}{16} = \cdot 00187 \text{ inch.}$$

This is somewhere near the amount required, but should not be exceeded.

In actual practice, this theoretical figure is impractical because the clearance can only be measured by inserting feeler gauges between the punch and die, and for this reason the experienced toolmaker usually allows ·001-inch clearance all round for every ·030-inch thickness of material to be cut. On the try-out press it may be found that the tool could do with a little more clearance, in which case the punch and die are " eased " by either grinding or stoning.

Die clearance is a matter that requires very serious attention, because insufficient clearance throws additional strain on the press and can increase the blow required by as much as 25 per cent. ; in fact, a trained man can instantly detect a tool with insufficient clearance by the excessive " hammering " heard when working. On the other hand, excessive clearance reduces the life of the tool, as, due to wear, the die has to be periodically re-ground to regain a cutting edge and because of the die taper, known as " backing off," the opening increases in size each time it is re-ground. Thus if the clearance is excessive when the tool is new, the opening will soon be too large to produce a clean-cut edge. The following Table shows the increase per side for various tapers :

Amount Removed from Die Face (in.)	Angle of Die Taper (degs.)					
	½	1	1½	2	2½	3
·010	000087	·000175	·000262	·000349	·000437	·000524
·015	·000131	·000263	·000393	·000524	·000656	000787
·020	·000175	·000350	·000524	·000698	·000873	·001048
·025	·000218	·000438	·000655	·000873	·001093	·001311
·030	·000262	·000526	·000786	·001048	·001312	·001574

Die Draught.—All blanking and shearing dies, except those that eject the part from the top, must have " die draught," sometimes termed " die taper " or " backing off," the latter being the most commonly used expression. In the case of very expensive tools, where economic production depends largely on maximum tool life, or when the material being worked is fairly hard, the taper may be as little as ·006 inch per inch. For most

purposes, however, a half-degree draught on all edges, *i.e.* an inclusive angle of one degree, is general practice. For softer metals, such as soft iron, copper and certain alloys, this figure should be doubled, making a total inclusive angle of 2°. In the past a certain amount of " land " was left at the top, but modern practice is to carry the taper right through to the top. When a die is made in sections, " backing off " is usually done by grinding, but where the die is in one piece it is done by the toolmaker-fitter with the aid of the die-filing machine.

The main reason for die taper is that when the blank is struck the blow causes compression of the metal round the edge, which expands on entering the die opening: a succession of blanks one on top of the other causes additional expansion, and if the opening is left parallel or has insufficient draught it will ultimately burst.

Bending Allowances.—A difference of opinion exists as to the allowance necessary for bending, but from accumulated data over a lengthy period of tool design it appears that one-third of the metal thickness should be allowed, especially for mild steel and half-hard brass. If the tools are correct and do not needlessly stretch the metal, sizes can be guaranteed to plus or minus ·005-inch after bending.

Blank Diameter before Drawing.—Blank diameters for drawn shells are usually determined by experiment. It is very embarrassing for a designer to give figures on a drawing, in all probability carefully calculated from a formula, and then to be proved quite wrong when the product is " drawn up." This is mentioned as a warning against accepting any theoretical formula except as a basis on which to commence calculations when determining the blank diameter. The usual and safest plan is to make the drawing tools first, the blank diameter is then found by cutting and " drawing up " trial pieces with the tools until the correct blank diameter is ascertained. There always are, however, certain cases where the blank diameter must be accurately determined before manufacturing of the tool can be proceeded with.

Apart from calculation, blank sizes can be determined by the following three methods: (1) using " rough " mild steel drawing tools on a try-out press, (2) spinning a sample part in a lathe, and (3) carefully weighing a sample part made by hand. The first suggestion is the best, especially if large quantities are to be produced from expensive tools. The formula generally accepted as being the most reliable for plain square-corner cylindrical shells is:

$$D = (d^2 + 4dh)$$

or with corner radius: $D = (d^2 + 4dh) - r,$

where D = blank diameter required (inches),
d = shell diameter (inches),
h = height of shell (inches),
r = radius at corner (inches).

For shallow draws calculations can be made fairly accurately, but as the depth of the draw increases the calculated figures become less reliable.

CHAPTER 13

DRAWING DIES AND THEIR OPERATION

THERE are many varied examples of drawing dies in use at the present day in mass-production factories, some very crude, others elaborate and expensive. No hard-and-fast rules seem to be employed in the selection of the type of tool; it is merely a matter for the personnel to decide the tool which will be used. It is not being unduly critical to say that in many drawn fabrications the method adopted could be improved. This does not necessarily imply that the people concerned in producing the article are at fault; they may be quite conversant with the fact that there is a more efficient method, but it is a very difficult matter to scrap a set of press tools, costing perhaps £500, and re-design at a similar, or perhaps a greater cost, to do a job that the firm with the same tools have in all probability previously manufactured in millions.

Nearly everything in the mass-production engineering factory has been evolved and not invented outright. There are naturally many individuals anxious to accept the credit for certain designs in most of the elaborate and wonderfully efficient tools that are in use at the present time, but if it were possible to trace back to the beginning of the production of any particular type of job, the above statement would probably be found correct in nearly every instance. Many of the very tricky deep-drawn components fabricated at present were evolved as a result of several years of progress. Perhaps in their original form they were made by a tinsmith or some other sheet-metal worker, as these craftsmen were in the past the cleverest metal-workers of all. Gradually, however, the original design was improved in order that production could be made more efficient and rapid. Take as an example domestic utensils of a few years ago and to-day; the old-fashioned tin kettle with its seams and bits of solder, compared with the "drawn-up" article on sale now. The majority of these articles are fairly easy to make with the necessary tools and presses, and if the product will permit of a few crinkles, like many of the cheap utensils on sale in the stores at present, they are so much easier to produce.

For the bottom of a saucepan or kettle a disk is developed and cut out on a revolving cutter—that is if a blanking tool is not available—and it is just pushed through a die in a single operation (Fig. 268). If it requires a more perfect draw, the finish to be smooth and uniform, then it will be drawn in a die constructed for a double-action press. An ordinary type double-action press is constructed with two distinct rams

working in unison. One ram controls the pressure pad which descends and holds the material to be drawn, while a central punch descends and draws the metal (Fig. 269). In order to complete the cycle, the upper tool ascends usually through the pressure pad, which strips the "drawn-up" part from the punch and then itself returns to the top. In the drawing of very thin material to any appreciable depth, this type of tool is absolutely necessary. If, on the other hand, the gauge of the material being drawn is heavier and no double-action press is available, then probably it can be drawn and finished to specification by two or more operations in a single-action press. If it is a very deep-drawn cylinder or container, with a certain gauge of material called for, and upon experimenting it is found that the percentage of "breaks" is too high, then the thickness of the metal would have to be increased and the tool modified to suit. With fairly substantial metal of $\frac{1}{16}$ inch thickness or thereabouts, it can be drawn in multi-operations and one or two annealing processes superimposed, but this is not practical with a deep draw of very light stock.

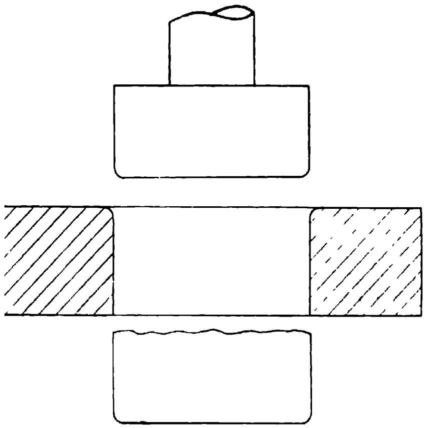


Fig. 268.—Simple die for producing kettle bottom in single operation

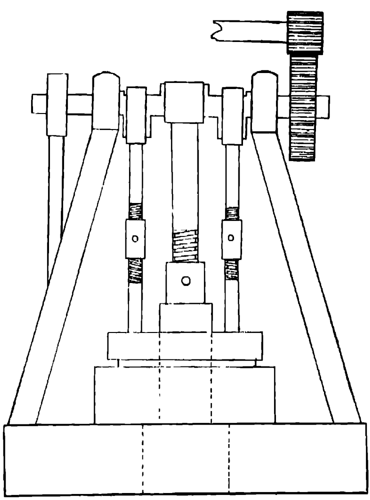


Fig. 269.—Explaining the design of a double-action press.

In some large works, especially those employed on motor-car body production, they have a portable heater, mounted on a wheeled frame, accommodating an assortment of high-pressure gas jets which are adjustable. These are arranged and set to heat the sheet metal in those spots where the greatest draw takes place and where it is liable to crack. The machine is then placed adjacent to the press and the sheet metal locally heated before drawing.

Shallow Drawing Dies.—Some short time ago the writer was responsible for the construction of a batch of tools to produce a paint-box to contain water colours. In the normal way it would have been a fairly simple job to design, but there were two distinct features to consider. First, that the material—which was mild steel, approximately ·010 inch thickness—was to be painted white on one side and black on the other before being drawn. There were an assortment of sizes which varied from twenty to forty compartments (Fig. 270). The second feature was that the box, when finished, had to be produced at a cost of practically nothing. After considerable thought and consultation, the definite conclusion was arrived at, that the top or the bottom, in each case, would have to be produced in two operations on single-action presses, to gain speed and rapidity of action. The first operation would be blanking from the strip. The second operation would be to draw up the sides and emboss in one blow, and by these means it was possible to keep within a reasonable price. The drawing and embossing tools in this instance were made first, as to develop a blank from any theoretical formula was entirely out of the question owing to the great uncertainty as to how much metal the embossing would take up.

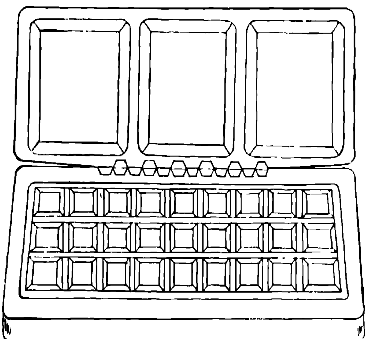


Fig 270.—The metal box—to contain water-colours

The blanking tools were made of the pillar type, with cast-steel bolsters, and the dies were machined out of the solid. It would, perhaps, have been preferable if the dies had been made in sections, as one die cracked in operation. This, however, did not prove such a disaster as was at first imagined, as it was possible to cut the cracked section away with the grinding machine and insert a piece about 2 inches wide. One other alteration had to be made and that was to recess the bolster ¾ inch deep by end milling, to withstand the outer pressure of the blanking stress. When the die is in a complete ring this is not necessary. Very

large tools, even when the die is in sections, are not always recessed for thin material, but good stiff dowels, ⅝-inch diameter, are found sufficient to withstand the outward pressure.

The sheets of metal were cut by a guillotine to a size suitable to be fed into the tools for blanking out (Fig. 271). These blanks were then drawn up and embossed in one blow with the special tools designed for the purpose (Fig. 272). The tools did the job and produced the article with great rapidity, but the amount of stress and hammering was considerable. Great trouble was experienced in getting springs to withstand the repeated blows and they were constantly renewed.

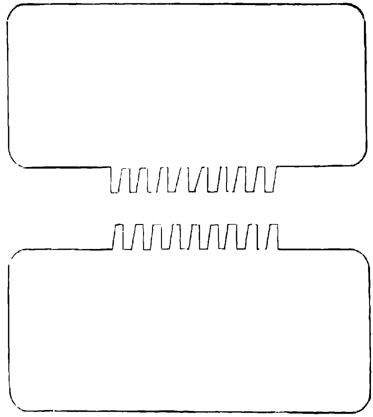


Fig 271.—Blank used in forming the metal box.

It will be seen from the illustrations of the tools, that the design is essentially to make a single-action press do a double-action job by means of innumerable springs, some of which are shown.

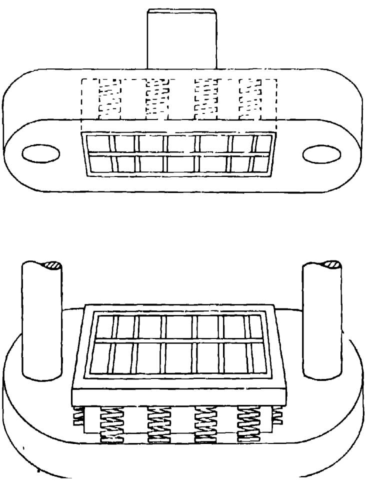


Fig. 272.—Single-action tool used for forming one operation

It is possible, that after the tooling costs were taken into consideration, the job proved unprofitable, and the trouble experienced served as a lesson in the design of subsequent tools, *i.e.* to avoid springs wherever possible. If tools must be of that nature, then rubber should be used in preference to springs, or better still, if in any way practicable, the tool should be so designed that the action is positive, and experience teaches that this line of design is the best to follow.

As an example, it may now be explained how this job might have been attacked, although by this method the tooling would have cost double and the production costs would also have been doubled, but against this the maintenance costs would have been exceedingly small and the tools might have " stood up " to the production of ten times the quantity.

Improved Method of Production.—In the first instance, a blank could have been developed that would have allowed for the embossing, the drawn-up edge, and about ·020 inch trimming all round. It may have been possible to guillotine these, although the square corner may have caused crinkling, and it must always be borne in mind that the more one can shorten the outer edge, to reduce resistance, the more chance there is of drawing the metal and not stretching it. The hinging tags could have been left for a later operation by notching, and the blank left plain (Fig. 273). The embossing tool in this instance would have been quite plain and without pillars, these being unnecessary, as the female and male embossing would have aligned themselves without other aid.

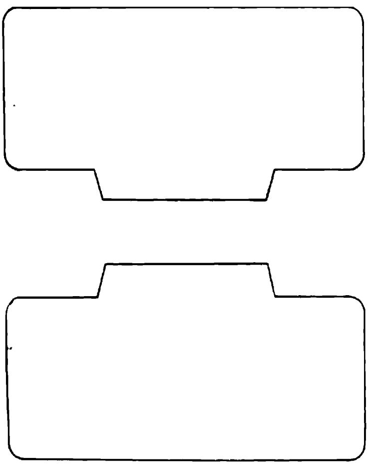


Fig. 273.—Blank to be used in another method of producing metal box.

The next operation could have been trimming and notching, with an ordinary follow-through type of blanking die to have trimmed the already embossed metal to size and notched the hinging tags. After this, the sides would have been drawn in a double-action press by a tool with a solid top and bottom representing the embossing, while an outer punch descended, drawing down the edge (Fig. 274).

Other Shallow Draws.—Shallow cups and rectangular flanged lids may be made from blanks or strip, on both single and double-action presses, the tools being very similar to those used for cupping, with the exception that usually the dies are constructed of a solid bottom and either with a spring or positive ejector. Dependent upon the quantity to be produced, the tools are made from hardened carbon steel or good-quality mild steel, and in many present-day tool-rooms, skin-hardening by the cyanide process plays an important part.

For the production of parts such as headlamp bowls or reflectors the

tools consist of just a shallow ring and the drawn part conforms to the shape of the punch. The pressure applied to the blank-holder or pressure pad is very considerable, in order to prevent too much slip, as the forming is by a process of stretching and thinning the metal. There is a limit, of course, to the amount that metal can be stretched and thinned, and it is only by experience and experimenting that a balance can be found between slipping and stretching, and the material must, of course, be sufficiently ductile to avoid fracture (Fig. 275).

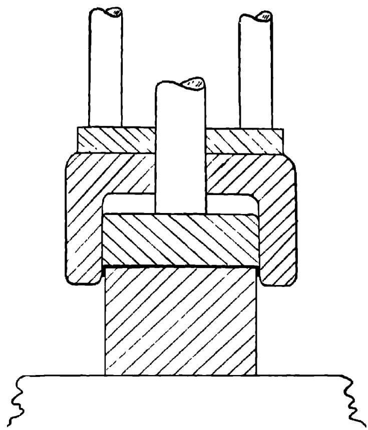


Fig 274.—Finally forming edge of box in double-action tool

Large Work.—When drawing large products, such as motor-car body wings, owing to the unusual area occupied by the tool and the inability to trap sufficient metal as resistance against the draw, the outer edge of the top die has a deep groove running round it and the bottom die is fitted with a half-round beading to correspond. When the upper die descends, the material being drawn is trapped by the bead, which exerts sufficient pressure, while the central punch draws the metal. These wings are drawn in pairs

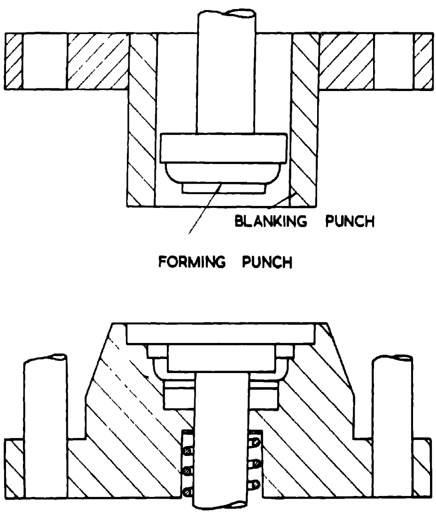


Fig. 275.—Forming shallow cups—double-action.

and afterwards split down the centre, as will be seen from Fig. 276. The majority of these tools are constructed in cast iron, the bottom die doing practically nothing, except to act as a blank-holder by supporting the bead while the material is drawn by and conforms to the punch. The punches for some of these tools weigh two or even three tons and are formed, after being cast to somewhere near the shape, by the Keller machine, which is a very large profiling machine operating various-sized milling cutters, which trace out the shape from a wooden model. The presses used to operate these tools are very large, some of the beds being 12 feet long. They are mostly of the double-crank type. The ram to which the top die is fixed is operated by compressed air, while the ram controlling the central or drawing punch is electrically driven. The use of these presses considerably simplifies this particular class of metal drawing, as the pressure holding the blank or sheet can be regulated to suit.

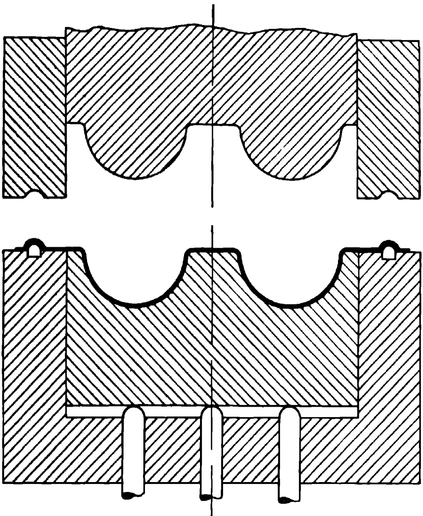


Fig 276.—One method by which motor-car wings are drawn—showing beading.

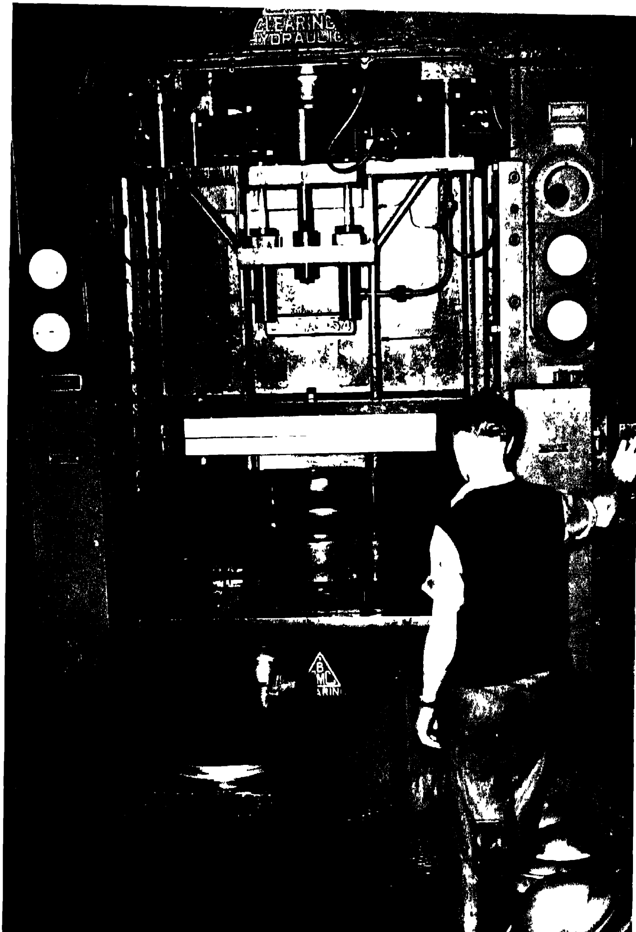
Deep-drawing Shells.—In the drawing of deep shells much experience is necessary to produce the required depth without employing any needless operations. When dies for progressive operations are designed and obtain excessive reduction in diameter or changes in form that are too acute, the metal will be over-stressed, if not fractured. On the other hand, if unnecessary re-drawing operations are employed, the cost of production is considerably increased. At a point between these two extremes there is a safe and economical course to follow and it is the ambition of the tool designer, in collaboration with the engineer, to determine just where this course lies.

An essential principle in any sequence of operations is to arrange for decreased reductions to be performed, if possible, at successive stages ; also

(*The Nuffield Organisation*)

LARGE PRESS WORK

Two interesting examples of large press work in the automobile industry

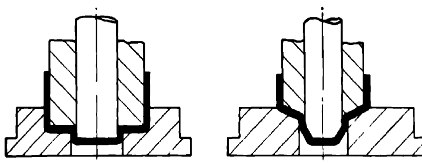


(*Ford Motor Works, Ltd.*)

A DOUBLE-ACTION HYDRAULIC PRESS

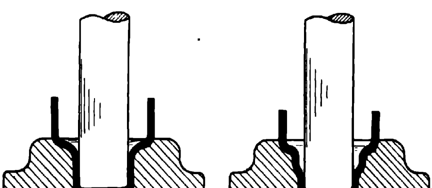
A British "Clearing" DH-170-54 enclosed-type double-action hydraulic press used in the manufacture of hub caps, radiator upper tanks, etc.

to divide the work between reduction of total diameter and reduction of metal thickness. The great importance of this distribution of the total work cannot be over-estimated, and it may be said that most of the obstacles to efficient production are from a lack of appreciation of this principle. It is frequently found that greater reductions are attempted at later stages than at the beginning, which is decidedly wrong. The reductions which may be performed vary a great deal with the particular product; for instance, much more work can be performed upon heavy-gauge material than light. In single-action re-drawing, the reductions which may be adopted are in the region of 30, 25, 16, 13, and 10% in the successive draws, but for light-gauge products, necessitating double-action presses, the first re-draw should not amount to more than 20%. In the process of re-drawing operations, which require only an alteration in the external diameters, with little alteration in the thickness of the material being used, a number of different methods can be adopted. In Fig. 277 A and B the drawing operations are carried out with blank-holders in double-action presses.



A B
Fig. 277.—Re-drawing by double-action tools A and B.

In the first operation for a re-draw, as in A, the metal has to make two right-hand bends, which imposes considerable strain on the material, whereas in B the blank-holding surface has approximately a 30° angle, so that the metal makes only two bends, through 60°, thus considerably easing the strain. For methods of reduction, as in Fig. 278, this process is usually employed for fairly thick-walled products, where a deep cylinder is required and annealing stages are possible. It will be seen that in method B the work is divided between the two steps so that heavy reductions may be used, in fact, reductions up to 40% can be made by this method. For the group of re-drawing operations, as in A, single-action presses are almost invariably used. A hole is drilled in the punch to avoid the formation of a vacuum, which would make the stripping of the component much more difficult.



A B
Fig 278 —Other methods of re-drawing A and B.

The " inside-out " method of re-drawing, shown in Fig. 279, is favoured by many designers on account of its simplicity. It is particularly suitable for rectangular shapes, as the reduction is considerable.

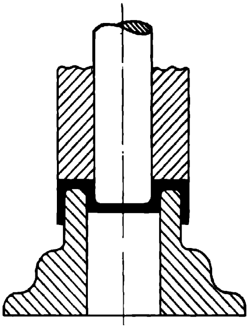


Fig 279.—Design for very deep re-drawing

Further examples of re-drawing methods, through which one can visualise the various forms that a component should take in the process of fabrication, are illustrated in Fig. 280, the blanking having been done separately with a standard tool. The first draw of a flanged case is shown at A, and this needs very little explanation, except that it was a tool of the " ejector " type operated in a double-action press, although a very similar job could be done on single-acting presses, and provided that the punch and die have exactly the right amount of clearance and that the material is to the stipulated size, there is no reason why it should not always be done so.

Fig. 280 B shows a first re-draw which reduced the size of the body from 2¾ inches to 2 inches, a single-action press being used for this operation, fitted with a platform and a spring-loaded plunger, which served the dual purpose of maintaining the case in a vertical position and also ejecting it after drawing.

The next operation was to reduce the bottom end of the case preparatory to the final draw, and was accomplished in a tool similar to that shown in Fig. 281 A, a single-acting press with a positive knock-out being employed.

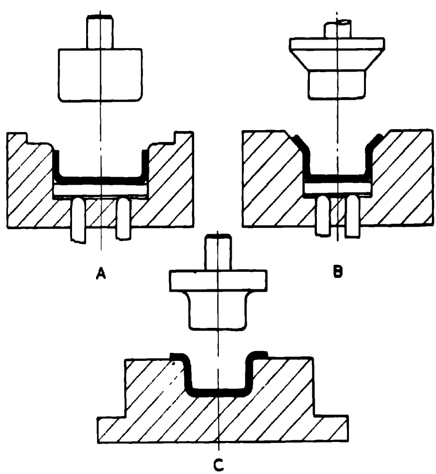


Fig. 280.—Single-action re-drawing to produce flanged shell, A and B.

The final draw must be done in a

double-acting press (Fig. 281 B), as it is necessary for the flange to be held very tightly whilst the drawing is completed. In the tools for the second and third draws, strippers were fixed to the bolster with mild-steel pillars and the component placed in the entrance to the die underneath the stripper bars. Usually in a component of this shape it holds to the punch, but should anything occur causing the product to fracture or split, then it will stop in the die. As it is a trouble to extract the part, and this may possibly hold up production, it is always best to forestall this and have ejectors, as well as strippers, to both punch and die, if only to give a start, and this will usually keep the tool clear. The fact should, however, be emphasised that, wherever possible, a punch with a taper, however slight, should be used, as this is always a great help in drawing and stripping. It frequently happens that a component of the deep-drawn variety is required to be made "parallel" by the production department when actually there was no reason whatever why the product called for should not have a taper of, say, 1°.

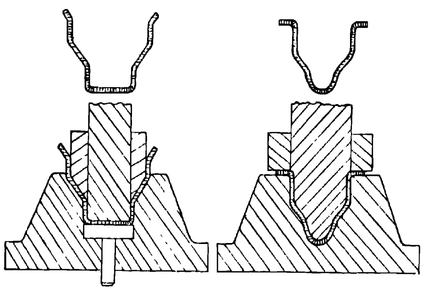


Fig 281.—Third and final draws to produce flanged shell, A and B.

The Eliminator Box.—In the life of a tool-maker, if one moves about a bit, from shop to shop, one is almost bound to come up against varied circumstances, and it is of great assistance in gaining experience. It must not be supposed that all production factories possess an adequate staff such as tool-planning department, engineering department, tool designing and drawing department, and so on; indeed it is often far from being so. Many large firms possess none of these useful personnel, and the practical tool-maker may be said to be the pivot upon which the factory revolves. The tool-maker is consulted by the works manager or foreman about a certain job, which it has been previously decided shall be manufactured, and he is nearly always instructed to keep the cost down. This raises the question as to how many operations are required. But for good results one should be very wary in cutting operations, as generally the onus of responsibility rests solely on the tool-maker. This, of course, is where experience is so valuable.

Round jobs are always the easiest to produce, rectangular and irregular shapes the most difficult, especially if sharp corners are called for, so, wherever possible, avoid them. Thus, in the production of a box for an electrical eliminator on cheap lines, the writer was rather doubtful as to

the possibility of doing it in two draws and had left room to superimpose a further operation, but it was successful, and the percentage of " breaks " very small. The box (Fig. 282) measures 6 × 4 × 2½ inches deep, of ·025-inch mild steel, and to attempt to accomplish this in one draw followed by a squaring operation was rather drastic.

For a cheap job of this description a cast-iron die and a mild-steel punch are used, and it is surprising how long a cast-iron die will last with adequate lubrication, and, moreover, with the constant slipping of the material on the surface, it becomes highly polished and hardened. In a difficult draw of this acuteness the use of a cast-iron die is to obtain balance, which is essentially a tool-maker's job.

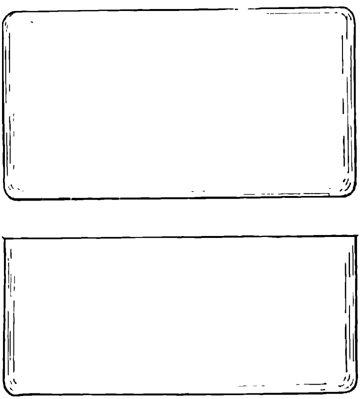


Fig. 282.—A deep rectangular box as explained.

The die was made from a good close-grained cast bolster, 4 inches thick, and the rectangular size of the box was drilled and slotted out, including the radii in the four corners. The bolster had been previously machined on either side and was afterwards scraped by hand to ensure perfect flatness, which is very necessary. The pressure pad was also made of cast iron, machined, and scraped flat. The die was then given a ⅜-inch continuous radius on the top side as a lead in, smoothed off, and nicely polished with emery cloth.

The punch for the first draw was machined from mild steel, with a $\frac{5}{16}$-inch continuous radius round the bottom edge, also a 1° taper from top to bottom. This taper is essential and it plays a very important part in the production of a clean job. Assuming that the die opening is 6 × 4 inches and the material to be used ·025-inch mild steel, the stock cannot always be guaranteed to size, so that an allowance of ·030 inch clearance between the punch and die should be made, which will make the punch approximately 5·940 × 3·940 inches at the top or largest end. The punch is 4 inches long with 1° taper, so that the bottom end of the punch will be approximately 5·804 × 3·804 inches, allowing then, when the punch first hits the material, at least $\frac{3}{32}$-inch clearance between punch and die, gradually decreasing as the punch descends, so that no ironing takes place until the end of the run in.

The tool for the first draw was then mounted in the double-action press and bolted down very firmly. In the try-out of tools where any side stress

is likely, the necessity for absolute immovability cannot be overestimated, as any movement destroys balance, and owing to the fact that no two trial pieces show the same result, it is impossible to make progress. As in this case it was not intended to make a blanking tool, but only to mark off templates, after final development a roughly calculated size of the blank was worked out. In the development of a drawn product it is always advisable to keep on the minimum or short side, otherwise progress will be hampered (Fig. 283).

With lubrication the trial piece was "drawn up" and afterwards carefully examined. The experienced man will probably turn the die round, after marking it, to find which gives the best result, and then the balancing job begins. Perhaps two corners are good, one has broken, and one has crinkled. The scraper is used round about on the top of the die where the break had occurred and about ·001 inch removed to lessen the pressure. On the corner that has crinkled, a little more weight on the pressure pad and so on, until, with patience and perseverance, the whole of the four corners draw up clean and unbroken (Fig. 284).

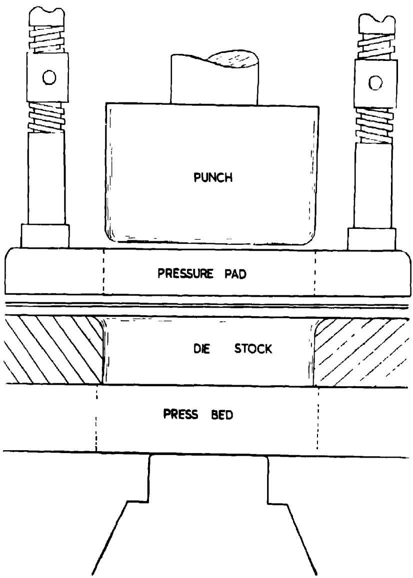


Fig 283 —Double-action tool for producing box

The next operation was squaring up and forming the bend on the bottom edge. A die was made from cast iron about 4 inches thick, and milled out to the requisite size, with 1-inch square steel inserts all round the top edge. The punch was made in this instance from cast steel to exactly the same size as the previous one, but with the bevel, and it was afterwards hardened and tempered. In the bottom of the die was fitted a large-headed knock-out as a precautionary measure, and four small airways were filed in the underside of it, to stop the bottom of the drawn box blowing in, also an air passage was drilled up through the punch to stop the reverse occurring (Fig. 285).

All that was then needed was a trimming tool for the top edge, and this

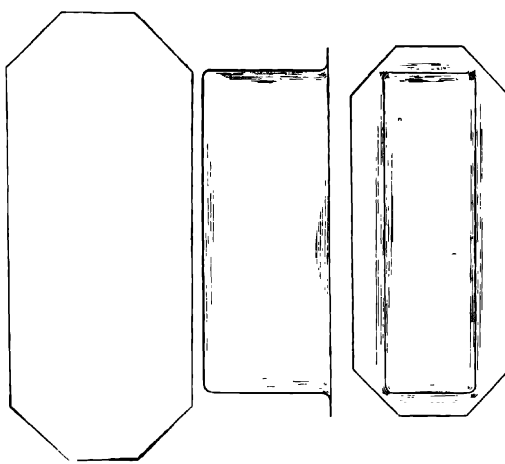


Fig. 284.—Blank and first draw for metal box

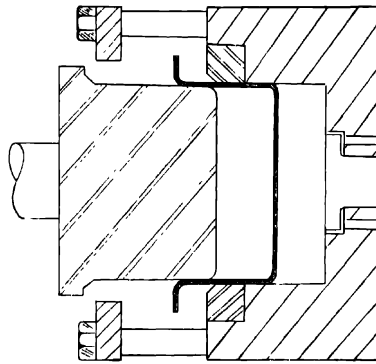


Fig. 285.—Second draw and bevel-tool metal box.

was quite a simple matter. A trimming tool of the blanking type was made, with a die in sections. On to the bottom of the blanking punch was a pilot which entered the drawn box, also a spring stripper was fitted to strip off the trimmed portion, and the whole job was now complete (Fig. 286). Many thousands of these eliminator boxes were subsequently produced with this tool.

Multiple-drawing Dies.—This type of tool is sometimes employed in the press shop with the intention of reducing costs by minimising labour. These tools, however, especially if they are of the automatic indexing variety, sometimes prove unsatisfactory owing to increase in maintenance costs and production time losses. But simple tools for multiple piercings, where the perforations are too close to each other for a

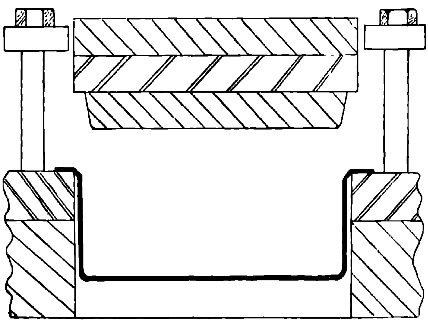


Fig. 286.—Final trimming tool ("blanking type") for producing rectangular box.

single- or double-operation die to be practical, prove very successful. They are constructed with a die usually recessed into a bolster but able to turn freely. To the upper part of the tool is affixed a handle and the revolving movement is indexed by a spring pawl. If a fabrication requires a large number of piercings and embossings, this amount would be divided by three or four. The press would be operated by single strokes and after each blow the tool would be pulled round, until the pawl entered the next notch, when the press is operated again (Fig. 287).

The automatic indexing multiple-drawing die is a rather complicated piece of mechanism. The lower part of the tool usually accommodates the punches and is also fitted with an automatic indexing device, which controls the tool in its revolving motion, allowing each drawing punch to do its special job in turn, successively reducing the size of the drawn part. Although each punch and die is performing an individual operation, a complete product is delivered at each stroke of the press. During a complete revolution of the tool the whole of the operations are

performed, until the complete product passes over a clearance hole and drops out. The material is fed in by roller or "gripper" method, and provided the tool does not break down, a very rapid and cheap method of production is obtained. This method is seldom used for high-class articles, but for products that have to be manufactured at highly competitive prices, such as a butterfly opener on a polish tin. An example of a piece made in five draws with a multiple-drawing die is shown in Fig. 288.

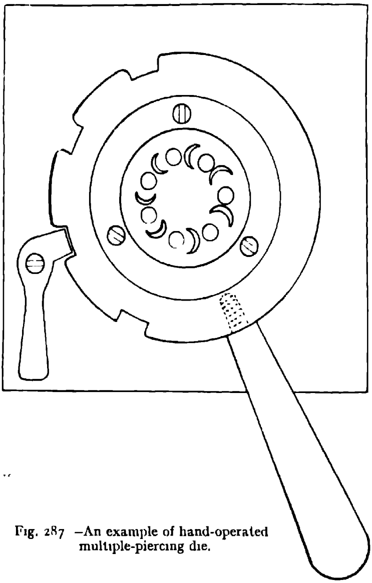


Fig. 287 —An example of hand-operated multiple-piercing die.

Many components produced by forming dies are very similar to those which have been fabricated in drawing dies. Although in many instances one term is used for the other, or vice versa, it is as well, if possible, to determine some line for classification. Undoubtedly the term "forming tool" should only be applied where the component produced distinctly conforms to the shape of the punch and die and resembles them in form, shape, and size. As an example, if a piece of metal is forced down into a die, both die and punch having previously been made the shape of the article required to be formed, and merely by pressure the metal is forced into the desired shape, then this can be termed a true forming tool. Where the part produced does not necessarily conform to the shape of the die and the form has been obtained by the thinning and stretching of the metal, then this can be considered a drawing tool.

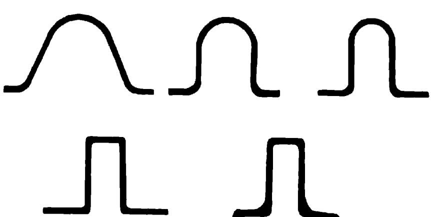


Fig. 288 —Five operations in a multiple tool.

Simple Drawing Die.—An extremely simple design for a drawing die is shown in Fig. 289. The blank has been previously cut in a standard-type blanking press; it is then placed in this tool and located by means of a shallow recess formed by having a circular hole, the same size as the blank, cut out of a piece of ⅛-inch flat steel, the plate being then screwed on to the die face. Some shops are in the habit of having recesses turned in the die to accommodate the blank, but this is not the best method to adopt, as, if at any time the rim of the cup has to be increased or decreased and the die has been hardened, it is a difficult matter to alter the size of the recess.

When the punch descends, it forces the blank through the die opening as shown, thus forming it into a cup. As the press ram ascends, the part is stripped from the punch by means of spring pins. These stripper pins are not really a necessity, as it is very unusual for a piece-part of this description to return through the die, unless the stock is very much undersized.

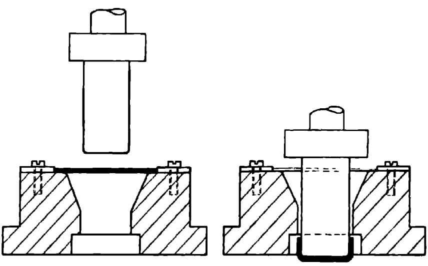


Fig 289 —Simple-type drawing tool—forming shallow cup.

Simple Re-drawing Die.—When a cup or shell has to be of a greater depth than approximately half its diameter, and if the material called for is of fairly heavy gauge, it is re-drawn in successive operations, dependent upon the depth required; by plain reducing dies in single-action presses and by a process of reducing the diameter and transferring it into depth: primary shallow shells of large diameters are transformed into deep shells of smaller width (Fig. 290, A, B, and C). In single-action re-drawing operations of this description, the amount of reduction must be done gradually and the part forced over a large smooth radius, otherwise, if the re-draw is done abruptly or suddenly, a groove is formed in the piece-part at every successive draw, which cannot be eliminated.

Inside Blank-holder Dies.—For thin work of any considerable size, a re-drawing tool of the inside blank-holder type is used, especially for long cylindrical parts where considerable reduction is necessary, as this would be liable to create crinkles. The previously formed cup is held by a blank-holder or pressure ring on the inside, as it passes between the lower bevel edge of the die and holder, while the punch descends. The pressure ring prevents the formation of crinkles, which might occur if thin material is being drawn and not adequately held.

These dies are used in double-action presses, as one ram is needed to

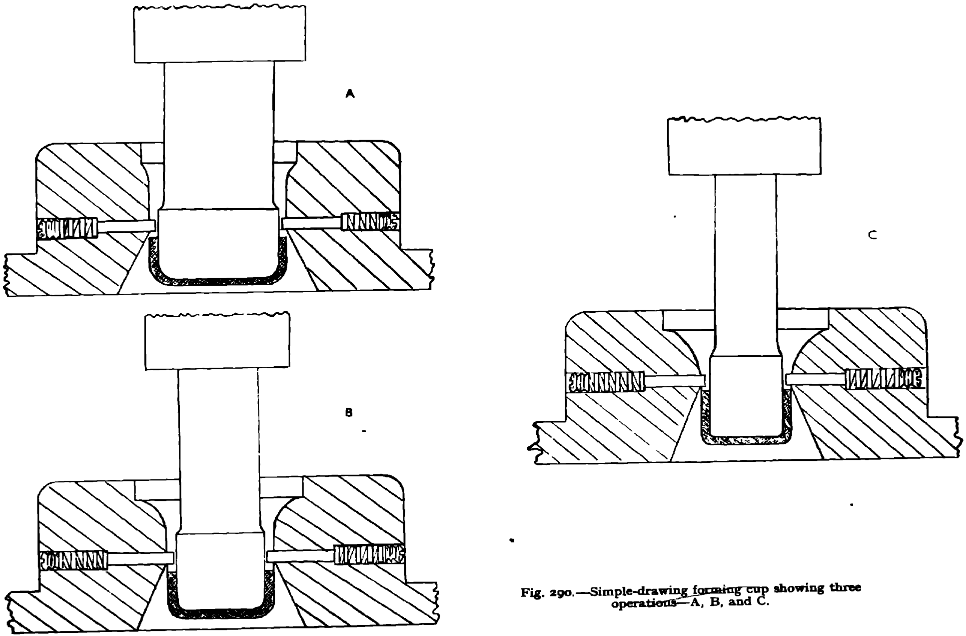


Fig. 290.—Simple-drawing forming cup showing three operations—A, B, and C.

exert pressure on the blank-holder, while the other ram operates the drawing punch. When constructed for the production of large articles, the dies are frequently made from cast iron, moulded by a special process and treated to give a very dense and uniform texture to the metal at the working surfaces. Steel rings are often set into cast-iron holders to form the drawing part of the die and the pressure ring is made from a steel casting, which adds considerably to the life and durability of these tools (Fig. 291).

Simple Draw and Pierce Tool.—There are many varied designs for the drawing and piercing of a shallow component, as this shape and class of article is in great demand for many purposes. The following tool, which was possibly unique in its simple design, construction, and operation, will be of interest. The component was made from 14-gauge cold rolled steel—blanked, drawn, and pierced, in two operations. Great care had to be exercised in setting this tool, as a great deal depends on the pressure applied by the rubber buffer, which is of the kind known as "the London-type buffer." If the pressure is too great, the diameter of the piece-part will be larger than the opening constructed to receive it in the die used for the second operation. But, on the other hand, if the pressure is insufficient, then crinkles will form in the shell, and these, when the final operation is performed, may develop into fractures.

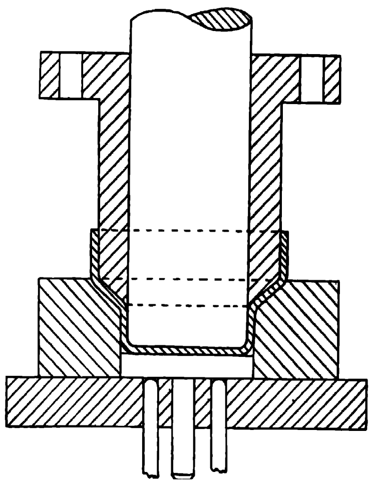


Fig. 291.—Example of a double-action inside blank-holder type drawing tool

The tool for the first operation of blanking and forming is of a simple compound type. The strip is fed in, underneath the stripper, and when the top tool descends, with the outer edge cuts out the blank, the disk being gripped by the punch coming into contact with the die-holder forced up by the rubber buffer (Fig. 292). The downward travel is continued, while the piece-part is drawn over the dormant punch at the bottom. With the upward movement of the ram, the tool separates and the drawn component rises clear by the action of the buffer on the

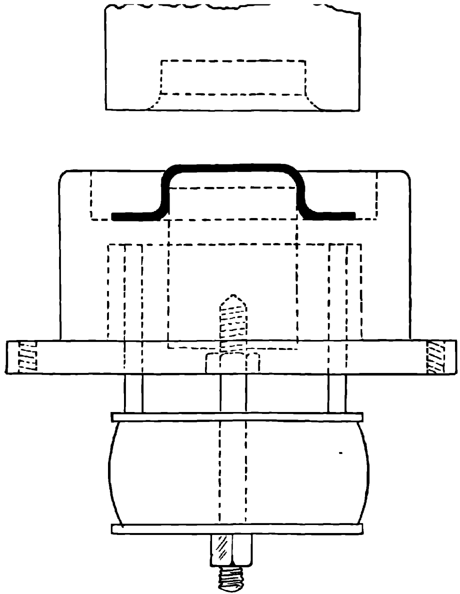


Fig 292 — Forming shallow cup—first operation.

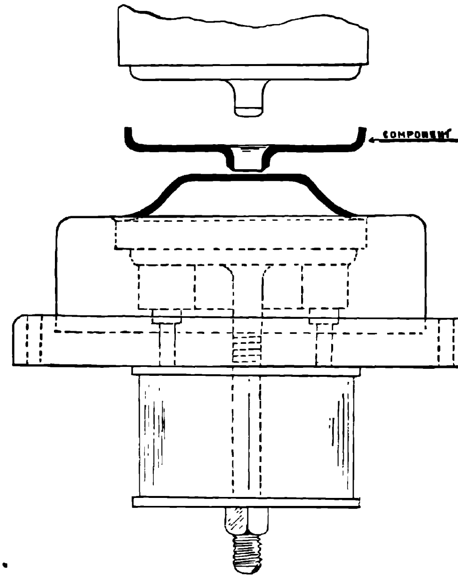


Fig. 293.—Re-drawing and piercing—second operation.

blank-holder, and if used on an inclined press, will naturally fall clear by gravity.

The final operation for this job is rather tricky. The component is placed on the tool upside down, and when the pressure is applied the outer rim curls upwards, until it hits on the shoulder at the outer edge of the punch. The downward movement is continued, completely turning the centre portion of the product inside out, finally piercing it at the bottom of the stroke (Fig. 293). Upon the return the component is carried up on the piercing punch until being stripped off by the fingers placed one on each side of the die, entering a groove on the punch.

Die-cushions.—Die-cushions of the pneumatic variety are used extensively in large production factories for obtaining uniform pressure when drawing metal on single-action presses, and they have proved very satisfactory. Various types of these accessories have been developed, mostly by American firms, and an example is shown in Fig. 294. This cushion is designed especially for small work, and to facilitate rapid production is usually used on an inclined press. In this design the piston is stationary and the cylinder moves, the piston being supported by a suspension rod which screws into the bolster. The bottom ends of the pressure pins are either resting on the top face of the cylinder or an additional plate made to receive them. Compressed air at the required pressure is admitted to the cylinder through the opening shown. Between this inlet and the compressor there is a container and regulating valve, so that the exact pressure needed for each product may be adjusted.

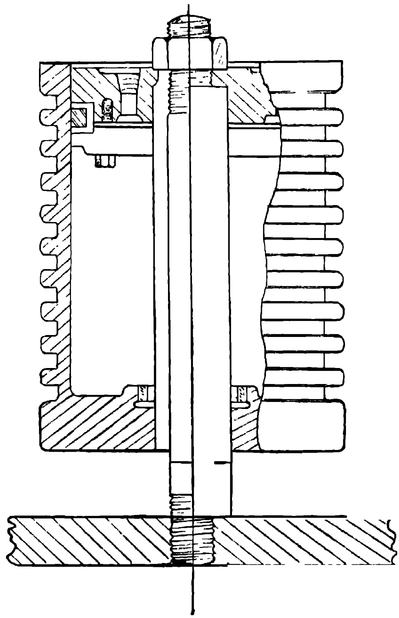


Fig 294.—Illustration of pneumatic die-cushion.

On larger presses of the double-crank variety several die-cushions may

be required, but these are of a different design. The cylinder in this instance remains stationary while the pressure pad, which is large enough to support all the pressure pins, is mounted upon the piston rods. The number of cushions used depends on the size of tool and the pressure pad that is going to be used, the latter usually fitting into the press bed.

These die-cushions are also made of the double-piston pattern for use on double-crank presses, which may be of either the single- or double-acting types. Three-piston die-cushions are also made for heavy-type double-crank presses. Where the pressure needed for forming a part is uneven and may cause tilting, a three-piston cushion may be used on one side and a single- or double-piston cushion on the other, to equalise the pressure.

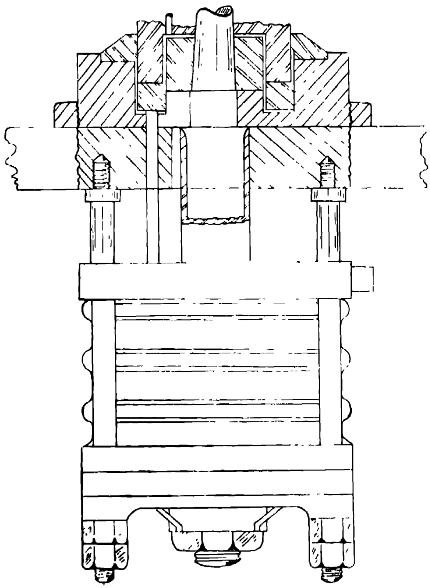


Fig 295.—Die-cushion used on heavy presses

For the purpose of blanking and drawing a cup and also piercing a hole in it, a special die-cushion is made with a hollow shaft, which allows the slug punched from the component to drop through it. A further type of die-cushion is fitted with a three-way valve, to allow the air pressure to reduce or escape at any predetermined position of the stroke, which can be regulated and adjusted by setting small cams placed adjacent to the press. All standard die-cushions are designed to be used with the usual air-compressor plant, which is now to be found in most production factories.

There are instances where the pressure for blank-holding is insufficient with the ordinary type of compressed-air cushion, and greater pressures are then obtained by the use of the hydro-pneumatic design of die-cushion. This type uses a liquid, usually lubricating oil, instead of air to gain the necessary pressure. The oil is stored in a tank and enters the cushion

through a cam-operated valve, which works in conjunction with the ram crankshaft. When the ram descends, the pressure pad is moved against the oil, which is forced through an air-controlled relief valve, back to the container. The relief valve is air-controlled, thereby allowing the operator to make a record of the pressures used on each job, the valve varying the resistance to the passage of the oil (Fig. 296). The use of die-cushions is becoming more and more prevalent, and they are of great benefit to modern scientific engineering production.

Besides pneumatic and hydro-pneumatic die-cushions, there are several mechanical attachments for regulating the pressure in press work.

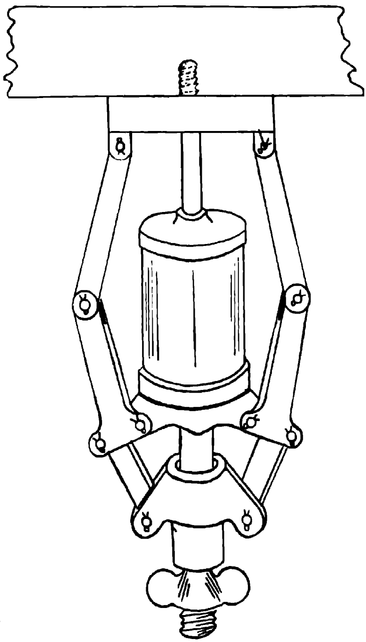


Fig. 296.—Toggle die-cushion attachment.

Toggle Pressure Cushion.—This attachment, which is shown in Fig. 296, is particularly suitable for use with combination dies. It is constructed to give uniform pressure on the blank, increasing the efficiency of the tools being used by minimising the stress on the material being worked, thus reducing the possibility of crinkles and fractures, and also adding considerably to the life of the tool. The idea of the toggle mechanism, which will be understood from a study of the illustration, is to reduce the amount of compression on the spring or rubber by the application of leverage. This reduction of compression makes possible the manufacture of deep shells and often reduces the number of operations required.

Rack and Cam Attachment.—This is another device for regulating and prolonging equalisation of the buffer pressure. This device (Fig. 297) is screwed on to the underside of the tool, the pressure pins being extended through the bottom, so as to come into contact with the buffer platform. When the die is depressed, there is a downward movement of the lower plate against the spring pressure caused by the action of the cams swivelling whilst being in mesh with the rack. The amount of pressure needed can be regulated by the hand nut at the bottom of the spindle.

Suitable Speeds for Presswork.—It is essential that great attention should be paid to the question of the most suitable speeds for presswork. Tools designed in the drawing office are usually planned for certain presses, this information being sometimes noted on the drawing, but the idea being merely to produce a tool capable of going under the ram when fully extended, which is called the "shut height." The particular press may, however, be very rapid or very slow in action. The correct values of the speed, for producing the article required, are then left to the practical man in the shop, either the try-out man, the press-room foreman, or the press setter. Presses of the self-contained type, having their own motor attached, usually have the necessary information worked out on a scientific basis supplied by the makers, with revolutions, weight and size of flywheel, etc., from which the calculations can be made for weight of blow.

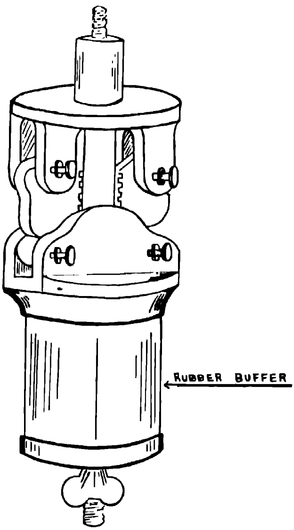


Fig 297.—A further die-cushion attachment—cam type.

With small press tools for brass, steel, spring nickel, etc., the presses require to be fast, especially if they are of the blank and pierce variety carrying very small piercing punches, not less than 250 strokes per minute being required, or trouble will occur due to the thin punches not having sufficient impetus to pierce the metal, and so they will bend and snap.

It is obvious that the size of the press governs to a great extent the speed at which it can move, but the area of the blank or draw, as well as the gauge of the material being worked, plays a most important part. Drawing operations require slow-moving presses, to give the metal being drawn sufficient time to balance and settle to its structural alterations, as well as to minimise the strain, which would otherwise result in fracture. The question of speed in relation to heat generated by friction, especially where cooling lubricants are not available in sufficient quantities, must also be taken into consideration.

Blanking tools with a shear on the die or punch always produce a cleaner component in a slow-moving press, which will be generally understood when one thinks of the cutting action of scissors. Bending tools are much more profitable when used in slow-moving presses of about sixty

strokes per minute, especially on the heavier-gauge materials of $\frac{1}{8}$ inch or over, fractures being less frequent and the bends cleaner and more uniform.

Unfortunately the press setter is often greatly handicapped in respect of operating speeds. He may get a tool to produce a certain job, and with his experience he at once realises the speed at which that tool should be worked, but the press he has available, to use a trade term, fails to " knock the component out " and jams. His only alternative is to put the tool in a faster-moving press to gain impetus and weight and this is often against his better judgment.

The following information on the subject of press jamming should prove to be of value. In a blanking tool, if, upon being set, the press is incapable of cutting the material and stops, it can be usually overcome by pulling the flywheel round and " bumping " it, until the punch passes through the material, when the tool can be transferred to another press. But in the case of a bending or forming tool, when the press is set the punch usually " bottoms." Now if the press is set too deep by a considerable amount, the ram will just descend and stop! But if this extra depth is a small amount, say about ·010 inch, the crank will spring and the press stop with the component or tool underneath it. Exactly the same thing occurs if two blanks are put into a forming tool in error. Perhaps it will be sufficient to remark as indicating the trouble which ensues that it sometimes takes two men twelve hours to get the press working again.

Lubrication.—One of the most important things which has to be considered in the fabrication of metal parts, especially where drawing takes place, is the necessity for securing adequate lubrication of the tools and material. For hand-operated and slow-speed machine presses, lubrication is not of much importance, and it usually appears sufficient to apply any form of lubricant at irregular intervals, but high-speed machines require a copious supply of the right kind of lubricant continuously in order to reduce friction. The usual practice of placing large quantities of one form of lubricant in the press-room and using it for all purposes, such as drawing, forming, cutting, etc., is not only very wrong, but very extravagant. To choose the lubricant of the right kind is a matter of intelligence and one of the principal problems in relation to speed and maintenance. The kind of lubrication that has to be employed is what is termed a coolant, and one that does not break down and allow actual contact between the metal of the tool or component, as it is this which will cause rapid wear of the tool being used as well as scoring of the component.

The ideal condition is to have a film of lubricant between the tool and the piece-part, but the attainment of this is an extremely difficult matter, and although many experts have spent much time and thought on the subject, information is still far from definite and complete. One of the most commonly used lubricants is soap solution, which is best used hot, as it has been discovered that its effect is then superior to when it is cold.

This liquid acts principally as a coolant, but it also has lubricating qualities. Sometimes considerable advantage is gained by the addition of an oil, either animal or vegetable, thereby forming an emulsion; a commonly used and much-favoured mixture being: water, 10 gallons; soap, 2½ lb.; soluble oils, 2½ lb.

One of the best-known lubricants for cutting and punching, and one that is often recommended for use when drawing copper alloy or brass, is lard oil.

For drawing steel a good lubricant and one recommended by many men of experience is: 25% tallow, 25% flaked graphite, and 50% lard oil. This composition is used hot and the metal run through it before entering the tool. For heavy steel drawing, another mixture which has found favour is: 1 lb. white lead, 1 quart shale oil, ¼ lb. black lead, the black lead being previously mixed with a pint of water before adding the other materials.

A drawing lubricant for heavy steel shells has been found in a mixture of lard oil and precipitated chalk. These two ingredients are thoroughly mixed together and afterwards allowed to stand, a jelly-like substance being thus formed. It should be mixed according to the gauge of steel being drawn, *i.e.* the heavier the material, the thicker the jelly.

The application of metal polish to the surface of metal strip is known to be of great assistance in the prevention of fouling, also zinc oxide and graphite have been used with success.

The fouling of tools, which is mostly due to the corrosion of metal particles on the die, and often on the punch, is a very important matter and frequently proves a costly obstacle, as it usually necessitates the removal and "taking down" of the tools and re-setting after cleaning. Metals vary considerably in their tendency to foul, and it has often been found advantageous to have those parts of tools that make contact plated with chromium.

Of the copper-alloy group, brass is the most important for drawing operations, because its fouling tendencies are of the lowest, allowing for long uninterrupted periods of economical production.

Drawing Soft Metals.—Aluminium and zinc are more plastic than brass or steel, inasmuch that they will accept considerably more deformation without tearing or cracking, and also can be given a greater succession of drawing operations without the necessity for frequent annealing.

The ductility of all metals is governed by their mechanical properties, and different tempers of the same alloy will have varying workable limitations. Aluminium has a much higher coefficient of friction than brass or steel, so that precautions must be taken when drawing it to reduce resistance as much as possible. With this end in view, all contact surfaces of dies and pressure devices require to be in a smooth, polished condition and greater attention paid to efficient lubrication. The pressure applied to hold the blank should be reduced to the minimum, in most cases just sufficient to keep the sheet flat.

Lubricant for Aluminium.—For drawing operations on aluminium fabrications, low-grade petroleum jelly is often used. Paraffin oil is sometimes applied, and is very valuable to prevent the tool from becoming "loaded," resultant from the abrasive action of the metal. Cylinder oil can also be used when working this metal, being found by many practical operators to give the greatest satisfaction.

CHAPTER 14

DIES FOR BENDING AND PIERCING

THE progress made with the precision bending of metal is on a par with that which has been made with other branches of engineering production. The bending of metal to obtain uniformity of shape is a difficulty which only experience in tool design and the use of scientific principles can overcome satisfactorily. After the blacksmith's or wrought-iron worker's method of producing a predetermined shape, which was usually to a chalk line drawn on the anvil, came the bending blocks, and of course these are still used in a great many industries to-day, especially on aircraft work, where the number of components called for may be only "one per machine" and it is therefore usually deemed unnecessary to make a precision press bending tool.

Bending blocks were usually made in several component parts, such as a solid block to maintain the internal shape, side and other plates fitted on pins to form the various radii which were needed to produce the component to requirement. These blocks were held fast in the vice with the sheet metal between them, the sheet being then bent and formed to the required shape with the aid of a heavy rawhide-faced mallet or a lead hammer. Undoubtedly this method was very satisfactory, within a very large margin of limits, on thin material, but it was almost impossible to produce two parts exactly similar, owing to various factors such as the natural springiness of the material being bent which could not be effectively overcome, while unequal distribution of pressure was another of the obstacles to accurate results. Bending blocks were made of mild steel, and if the component being produced had any holes in it, these were of great advantage as pins could be fitted in the bending tools to enter the holes in the component which had been previously drilled, and this would maintain the part in a definite position whilst being bent (Fig. 298).

Plain Bending Tools.—Success is gained by experience in the design of bending tools or, perhaps, one might say that experience is gained by failures in the design of bending tools, as undoubtedly one learns more from failures than from successes. With bending tools, as with most other press tools, in one class of bend the punch plays the most important part, and in another the die is the prominent feature, while in some cases both punch and die have an almost equal right to distinction. In whatever type of tool metal is bent, certain elementary factors must be kept in mind, one of these being that the metal must not be stretched

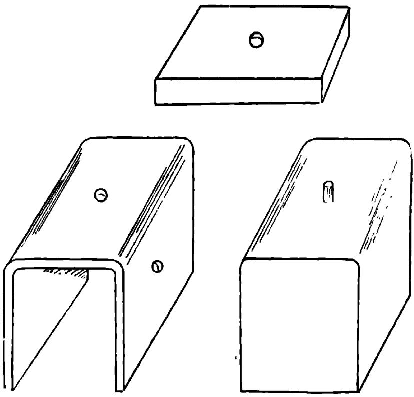


Fig. 298.—Bending blocks, also showing component after bending

and overstrained, otherwise it becomes weak and liable to break off very easily; another thing to remember is that when material is being bent in a tool made for the purpose, a great amount of distortion is caused by the strain which is almost impossible to recover or "push back" if the material is already trapped. This will, perhaps, be better understood from a study of Fig. 299. It will be quite easy to visualise from this sketch that when the punch starts the downward movement, the material tends to leave the underside of the punch as shown, and when the punch reaches the bottom, owing to the fact of there being a gap between the material and the punch, it is obvious that there is more metal than is required. Hence, the action of the tool is, if possible, to force the surplus metal back up the sides, but this it cannot do for the reason already given. So what really happens is that the metal forms a distorted wavy line in its effort to get rid of the surplus. When the punch is pulled up, instead of the sides of the component being at 90° as required, they will both lean in towards each other and the bottom of the bracket will be wider than expected.

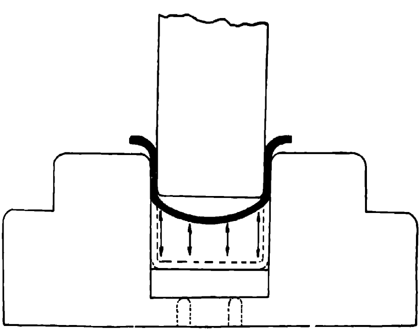


Fig. 299.—Bending tool, showing possible error.

To overcome this, the pressure pad was invented. For very light articles, dependent on the area and gauge of material, these tools can be made self-contained, that is, with springs underneath

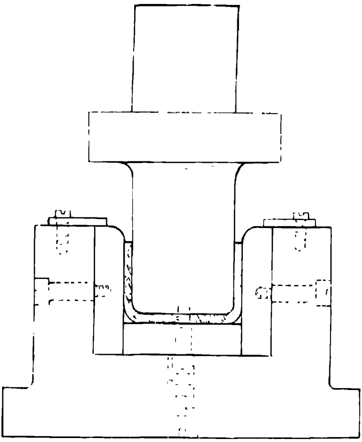


Fig. 300.—Bending tool—component in position.

the pressure pad forming part and parcel of the tool (Fig. 300).

The bolster is usually made of mild steel, and the punch, cheeks, and pressure pad of cast steel, which is afterwards hardened and tempered. The pressure pad is tempered down to a blue colour after hardening as it is liable to crack with the blow at the bottom if it is too hard. The punch is made to the stipulated internal dimension, but the cheeks are left slightly oversize and then ground to suit the material being bent, which in all probability will be in excess of the stipulated size. The complete set of components to make up a tool of this description, including the springs, is shown in Fig. 301.

It is absolutely necessary to keep the metal which is being bent in contact, as far as possible, with the pressure pad to avoid excess metal. Hence, as already explained, with the increase of gauge or thickness of material, we must increase the pressure in proportion, and if it is impossible to exert sufficient pressure by springs contained within the tool, then a large buffer spring or rubber buffer is placed underneath the bolster (Fig. 302).

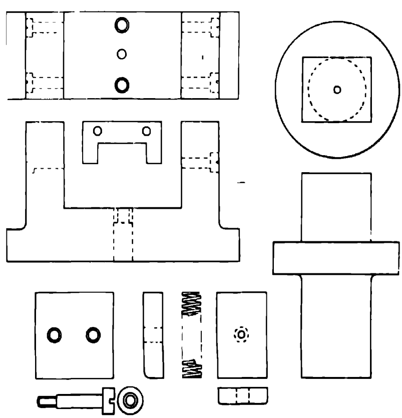


Fig. 301.—Details of a bending tool.

One must not be deceived into thinking that the greater the pressure, the better; indeed it is not so, especially if bending fairly thick soft metal

such as copper, brass, or zinc, as if the pressure on the metal between the punch and pressure pad is excessive, it will have a similar effect as in Fig. 299, not drawing too much metal in, but expanding and lengthening it by compression.

Vee Bending Tools.—Two arms at any given angle are best bent in a vee tool. This is a good class of tool for positive bending, as the flow of metal is even and unrestricted, so that the job is not liable to distortion. In many acute bends on thick or springy material, where the angle has to be to some definite figure, the tool has to be constructed to "over-bend" in order to allow for the amount of recovery due to the springiness

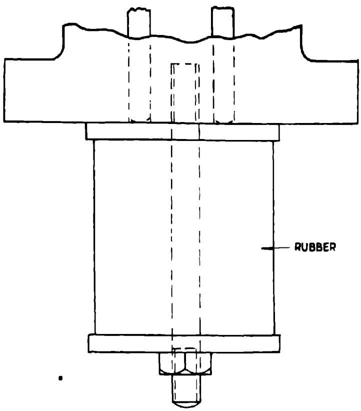


Fig 302.—Rubber buffer for bending; used when bending heavy-gauge metal

of the metal being bent. No set rule is observed, but where a bracket has to be at, say, 90°, the simplest way is to make a punch at 89° and a die to correspond, or if very springy material is being used and a considerable recovery is anticipated, then 88°. The reason for this is that if any modification is called for, especially with the die, it is easier to increase than to decrease an angle. If the bend has to be very sharp, the most economical method is to complete it in two operations, with an annealing process in between, as there are limits of endurance for all metals, and to have breakages occur when the part is put into use, merely shows bad workmanship. The vee tool illustrated in Fig. 303 is in a great many shops made from solid cast steel, but in others it is made from mild steel and skin-hardened in the cyanide bath when completed. The screw holes for the location plates are drilled right through but only tapped at the top, before the tool is hardened, the holes in the

location plates are not drilled until finally, that is, after the piece-part has been developed to size. These plates are usually held in position with a tool-makers' clamp, and supported on the hand-press bed with parallel strips, until the final adjustment is made to the length of metal, this being obtained by "trial and error." The tool is then turned over and the holes transferred right through into the location plates by drilling.

Multiple Bends.—It often happens that several bends are required on one strip of metal in order to form a single component, although, if the material is thin, it can probably be done in one operation. If the metal is of heavy gauge, it is usual to make two or more bends. Simplicity combined with thought, to discover the order of sequence and avoid overstress, is the keynote of efficient bending processes. A short time ago the writer was responsible for the production of an enormous quantity of brackets from $\frac{3}{16} \times 2$-inch soft alloy. They had to be positively square, free from fractures, and stretching and thinning had to be avoided, as they had to conform to the specification of Government departments. The radii were down to the lowest limit, *i.e.* the corners had to be as sharp as possible. The job could easily have been done in one operation, excepting for the snag that thinning had to be avoided. The brackets would certainly be checked over with a micrometer, and the thinning in the longest parts of the material would be discovered and quite possibly the job would be rejected in consequence. So, after giving the matter considerable thought, it was decided that two operations, with positive bends, should be employed. Because they are constant, the bends require no development, so that to find the exact length it is only the two ends that require alteration after bending, this being quite simple. In this instance, due to the quantity required, we made both dies and punches of mild steel, with cast-steel cheeks to the bottom tools and

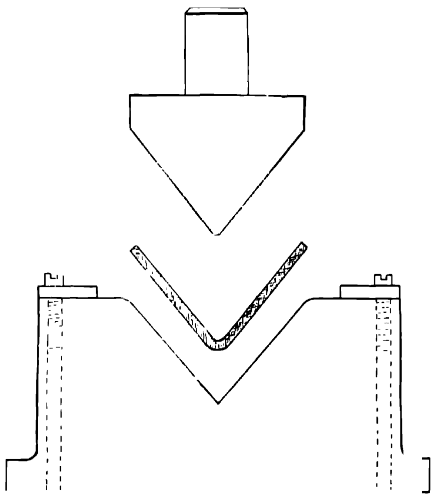
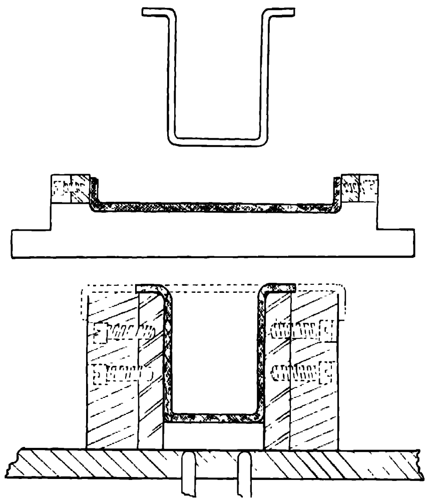


Fig 303.—Vee bending tool—component in position

corner pieces let into the punch to form the radii, as this is really the only part where any wear takes place. The pressure pads were made from mild steel carburised and case-hardened, as if practicable this is the better way. If they are made from cast steel, they are liable to crack with the sudden jar and distortion (Figs. 304 and 305).

Pillar-type Bending Tools.—The foregoing class of bending tool is quite good for many components, especially where each bend is to a certain extent balanced by the main stress being towards the centre line. Should this not occur, and the tendency is, perhaps, for one side of the component to run towards the centre and the opposite side away from it, then different tactics must be employed to retain rigidity and balance of power. Should the component to be bent have a sloping base, it is quite obvious that the pressure applied will be uneven and cause side strain. This can sometimes be overcome by a pilot on the punch to accept the pressure, or one part of this member entering the bottom tool in advance of the bending operation, but each and very job must be designed according to the shape of component, always taking into consideration the thickness of metal to be bent, as quite naturally this will govern the pressure needed. In several large production works where many years of good practical experience has been obtained in handling these operations, pillar-type bending tools are almost invariably used. This is particularly the case if the tool design follows American or Canadian practice (Fig. 306); it is a very sound idea, as the foundation of the job can be standardised, with a range of sizes, and the possibility of faulty setting is entirely eliminated, which undoubtedly is of considerable importance in bending. It is impossible for the tool gradually to work over, *i.e.* to get out of position by side stress, and uniformity will be maintained throughout. The top and bottom bolsters are composed of cast iron,



Figs. 304 and 305.—Bending a bracket—first and second operations

although sometimes cast steel is used. The pillars of good stout dimensions are constructed of mild steel carburised and case-hardened. It should be noted that cast-steel pillars are not used; they eventually warp as a result of the hardening stresses, and then sometimes cause a seizure. Oilways are recessed in the pillars to minimise friction, when side stress is imposed. The bottom and top tool in this type is usually composed of medium-quality cast steel, screwed and drilled in position after hardening.

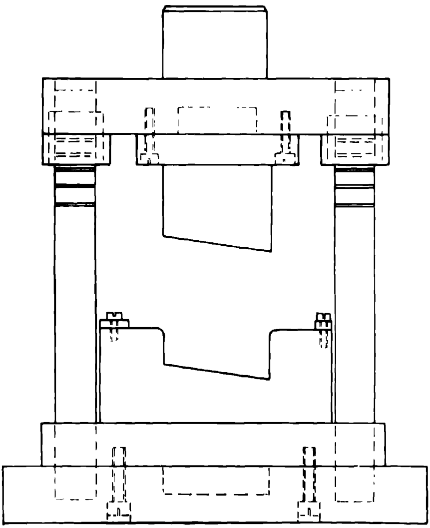


Fig 306.—Pillar-type bending tool.

To this class of plain bending tool it is unusual to fit any stripper mechanism, as the press can only be operated in single strokes and the piece-part is easy to remove. It is mostly pushed off by the operator with a metal rod, in the case of an inclined press, or pulled off with a hook when a horizontal press is used.

Bending or Forming.—It is very difficult to differentiate at times between the terms "bending" or "forming." If a sheet-metal part is shaped by confining it between a punch and die, and by their combined pressure the shape is directly reproduced, then this can be considered a "forming tool." But if, on the other hand, the action is confined to bending, as for example, when the punch passes a certain position and drags a lug of the piece-part to a desired angle or closes a gap formed by a previous operation, this should be called a bending tool. It will be realised that in the case of bending tools, not nearly the same amount of difficulty occurs in finding the development for blank sizes, and in the majority of components calculations made by simple elementary principles will be found to work out correctly. As an example, Fig. 307 shows a tube bent in two operations by simple tools in a hand or fly press.

Pierce-bend Tools.—In many instances it is impossible to bend articles in conjunction with a blanking or piercing operation, in the

majority of cases bending being a job apart. It is, however, sometimes possible to make a tool so that various operations may be performed on the same die-block, certain parts of the work being transferred from one section to another as the various operations are completed. In other cases it is often necessary to make several sets of bending tools to complete one particular article. When a stipulated number of components have been bent on the first die, the economical method is to have the tool for the subsequent operation set up in the adjacent press, and so on to the completion. If a highly paid experienced operator is working on the first press and less-experienced workers are employed for the following operations, the latter will be continually struggling to keep up with the production of the first press in order to prevent a "pile-up," and this should be avoided if possible. Pierce-bend tools are a standard product in a great many tool-rooms and fulfil a very useful purpose. The only difficulty about them is the development of the piece-part, to ensure the holes coming in the right position, as the importance of holes cannot be overlooked. For assembly purposes of wireless sets, telephone receivers, electrical instruments, etc., holes are useless unless they are within a tolerance error of ·002 inch.

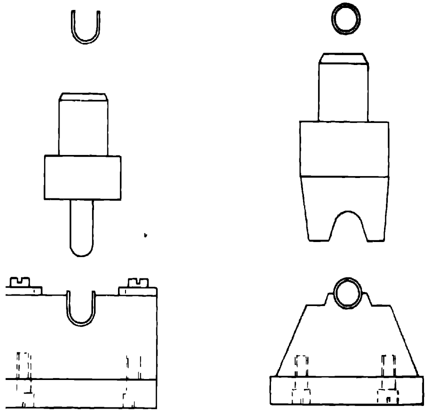


Fig 307—Tools for bending a small tube.

The little tool illustrated in Fig. 308 makes the small bracket shown in one operation, and to get the development the tool is made up to the previously calculated dimensions, the die being left soft. The piercing holes in the die and also the holes for punches are left out. The hole that accepts the stop is placed a little farther back than the calculation demands, as it is an easy matter to make various other stops of increased size. The cutting and forming punch is hardened and tempered, as this member will require no change. The material these brackets are made from is standard-width brass strip, which can easily be cut on the soft die without causing damage. A rough figure is arrived at, which should give the position of the two holes before bending, and these are then drilled in the strip, the holes being then checked over for any error and the results carefully noted. The strip is now fed into the tool and bent, after which it is

checked up to the piece-part drawing, and the holes either placed wider apart or nearer together, until the correct development is found. The piercing holes are then bored in the die and transferred through into the punch mounting. The die is then hardened, as very little, if any, distortion is contemplated with the modern tool steel, and even if there is two-thousandths of an inch shrinkage it is of no importance, as the dowels which retain the die on the bolster are not transferred until finally.

Blank and Bend Dies.—When bending articles of difficult shape, it is usually necessary to make the tool so that certain sections are bent before others. Should an attempt be made to make the tools solid in order to complete the job at one blow, owing to the material being held at certain spots, it would have to stretch to conform to the die form, and this should be avoided where possible. Where piece-parts are produced from very soft material, this is sometimes possible, but, as a matter of course, the metal will be thinner and narrower where stretched.

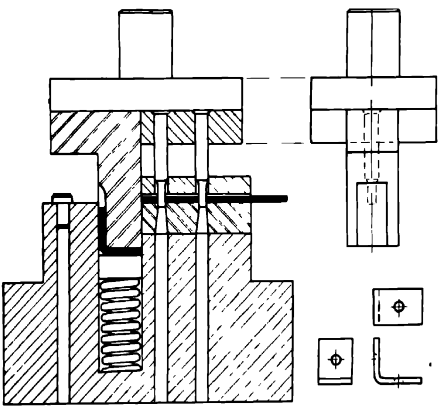


Fig 308 —Pierce and bend tools—making a small bracket

Blank-and-bend dies are very useful tools designed to cut the part from the stock and bend it to the required shape from the blanking punch, one tool performing the dual operation. Usually it is advisable to blank the part in one operation and bend it in another, but there are many instances where the two operations can be performed at one blow with success, thereby reducing the cost considerably. Besides an appreciable saving of time by eliminating one operation, an important saving in tool costs is also generally possible.

Convex and concave spring washers, which are extensively used in gun making and other work, can be made in very simple tools with a centre hole or not, as the case may be. As will be seen from Fig. 309, the washer is first pierced, then cut and carried down by the blanking punch ; pressed into shape on the spring pressure platform, and upon the return journey knocked off by the spring trigger, which is also operated by the blanking punch. One thing must be particularly observed and allowed for in the

construction of this tool—the piercing punch must not, under any consideration, come into operation until the main punch has severed the previous washer, as owing to the form being otherwise than flat, the material is pulled in towards the blanking punch to make up the extra amount needed for the form. This strain would be imposed on the piercing punch, if it had already entered the metal, and it would probably break off or make a very bad hole; also the die and punch would soon wear away, being continually thrown out of alignment.

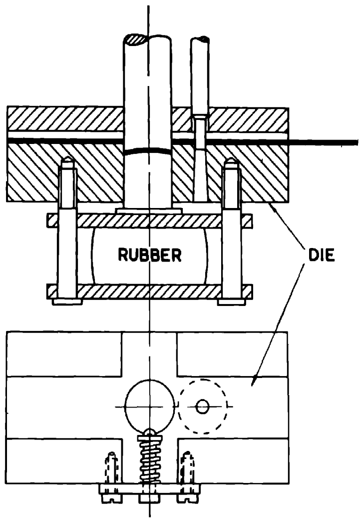


Fig 309.—Pierce and blank tool for spring washer.

Right-angle Bends.—Many parts can be bent up from the strip with as many as four distinct right-angle bends in a standard bending tool, by simply having removable locations which can be replaced by others. The material is cut off to length and one bend made on all components, and the location is then changed by the press setter, and a further bend made, and so on, until the whole of the operations are complete. These standard bending tools are usually made from good-quality cast steel, hardened and tempered, which will prolong their life and also enable them to retain their shape and form for an indefinite period.

Location plates are best made from gauge plate, which is flat silver steel, and these are also hardened and tempered. Many tool-makers fit tapered dowels, shouldered down at the top end and riveted into the plates. Tapered holes are reamered in the bolster to match up with these dowels, which are then toughened up. This allows the plates to be changed easily and without being knocked about. It is preferable to make the upper tool with the mounting made by the punch passing through the plate, a good tight fit, burred over and backed by a top plate or punch pad, as this method adds stability to the tool, upon which there is usually considerable side stress. The first operation consists of laying a strip of metal, previously cut to length, between the location plates; the punch then descends and forms one right-angle bend, leaving the other end of the material straight, as in Fig. 310 A; it is then turned round and using

the same location, the other end is bent up; the location plates are then changed, and the remaining two operations completed, B. Where there is sufficient gap, so that the material does not foul the punch when the bend is made, the uses to which this simple tool can be put are unlimited.

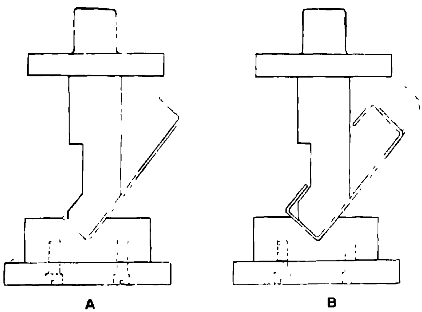


Fig 310.—Right-angle bend—first and second operation.

Cam Tools.—In the bending of some components, unless the punch descends centrally on to the material, equalising the pressure, there is always a tendency to drive the punch away from the work and the work away from the tool. There are several methods adopted for overcoming this; one is by the use of a spring pressure pad, which descends in advance of the bending punch and traps the metal by holding it very tightly. Another is the cam method, which it is considered preferable to springs, unless for thin material, as there is always a chance of movement with spring pressure, and the weight needed to hold a part, whilst being bent, is considerable. With the cam action, one part of the tool is in the shape of a leg with a set to it, and this descends prior to the punch, closing one block towards another, as in a vice. It is an idea which is used on many tools for various mechanical operations, such as—bending, forming,

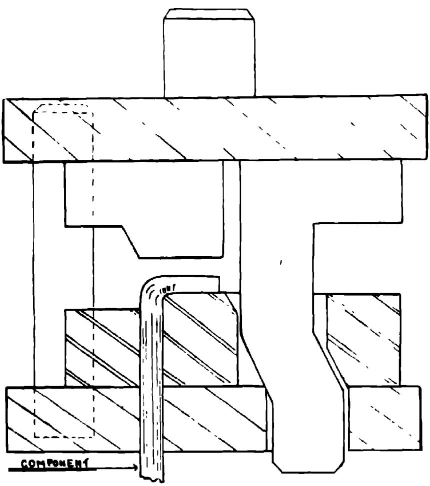


Fig. 311.—Example of a cam tool—bend and flatten.

staking, etc., and some tool designers develop a leaning towards cam tools which is sometimes annoying if there are simpler and better methods available. Fig. 311 shows the tool with the component after bending. It will be noticed that the short end of this piece-part is flattened, and as the bending punch performs this also, it will be apparant that the part requires to be held very firmly.

Cam-tool for Piercing.—There are many variations of the cam-tool, and there are many jobs which if produced by any other method would

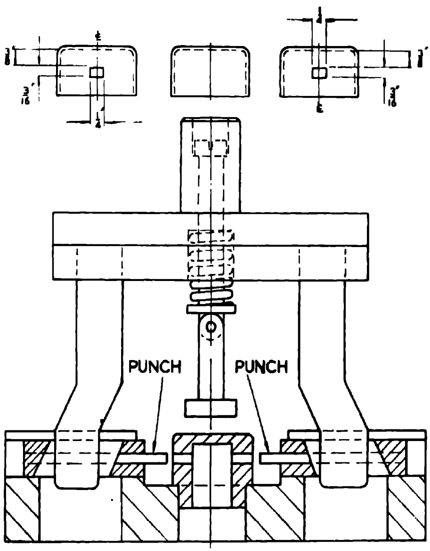


Fig. 312 – Cam tool for piercing two side holes.

cost considerably more. A cam-tool can perform two distinct operations at one stroke at practically any angle. As an example, consider the rectangular shell shown in Fig. 312. In "drawn up" articles it is very difficult to locate a piercing accurately because variations in metal thickness and temper cause slightly different results ; bending is quite another matter, as the amount of stress and stretch can be accurately calculated, and with properly designed tools the error can be reduced to the lowest minimum. This is not so with drawing, because although the inside and outside diameters of a shell can be produced to guaranteed dimensions, it

is not always possible to control closely the amount trimmed off to complete the three dimensions.

Thus if a small shell has piercings which must be controlled accurately to the production drawing, a simple method of precision piercing is to use a cam tool designed specially for the job. In the sketch of the component and tool (Fig. 312) only two side piercings are shown, but should four, six or eight openings be called for this would merely mean increasing the number of cams and slides as necessary.

The shell would be first drawn and trimmed, although some small shallow shells would not require trimming. The component is then placed on the location block, which is also the die, and when the press is tripped the descending cams force the piercing punches inwards through the material. The spring-loaded plunger seen in the drawing holds the component firmly during the operation and can be swung to the right or left to facilitate loading. During the upward stroke which completes the cycle the punches are withdrawn by the cams acting in the reverse manner. To minimise distortion, the die block, and also the form of the punches, is made to suit the shape of the component (Fig. 313).

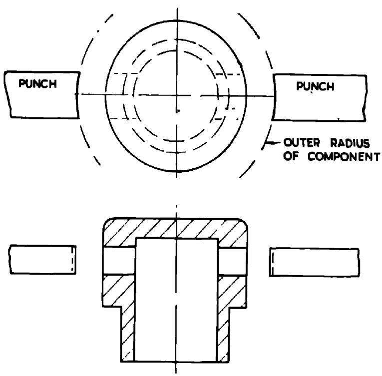


Fig 313 Showing how the die block and punches are shaped to suit the form of the component.

The life of both punches and the die block is limited: for instance, the die block cannot be re-ground. The punches, however, can be reconditioned several times by grinding because the "run in," *i.e.* the amount of excess movement after piercing has actually taken place, can be up to, say, 1 in. It is essential to keep the punches sharp and in good condition if the best results are to be obtained. The life of this tool is very good if the best materials are used. For instance, a new tool working on 18-gauge mild steel (·049) should produce 25,000 parts at a run, and the punches, excluding accidents, could be re-ground about ten times.

Shaving Tools.—Shaving is a process employed when extreme accuracy is necessary, and is the final operation when producing blanks for gears, racks and similar parts where it is essential for the form and dimensions to be perfectly accurate. It is not usual to shave a blank if the part is very thin, because, due to the lower pressure needed when punching out the piece, it is practically free from distortion. For a good, clean shaving

operation the maximum that should be removed is about ·005 in. When it is remembered that the whole of the energy exerted by the press is needed to sever the piece from the strip, it will be obvious that a shaving operation which removes only ·002–·005 in. of metal will require very little pressure, and thus the possibility of distortion and expansion is reduced *pro rata*.

In the case of a gear wheel of, say, $\frac{1}{16}$-in. material, the first operation may be to sever the blank from the strip material, omitting the teeth and leaving about ·005 in. plus on the diameter. The next stage would be to

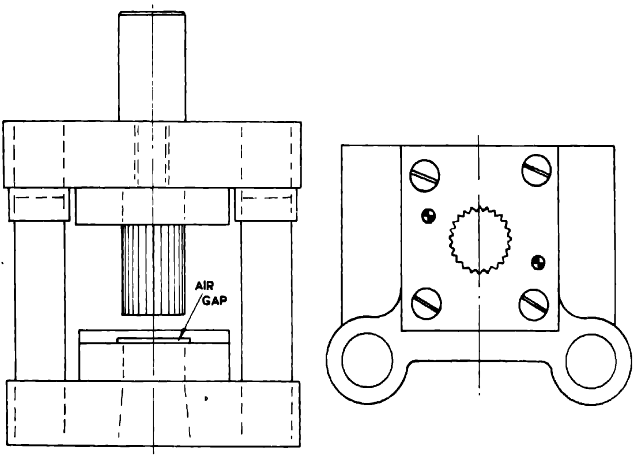


Fig. 314.—A typical example of a simple shaving tool

form all the teeth, leaving about ·002 in. plus: finally, the teeth would be shaved to very close limits and high-class finish. Alternatively, if wider limits of tolerance were permitted, the blank may be struck to form, complete with the teeth or projections, but if these were frail there would be "burrs" from the fracture which would then have to be removed by the shaving tool.

Shaving tools are very similar in construction to blanking tools, but it is essential that they should be designed either with guide pillars or mounted on a standard die set, as shown in Fig. 314. It is very difficult to get rid of the fine metal shavings, which are a source of danger, and thus for this class of work it is a practical necessity to provide an air line, with the nozzle blowing on the tool to keep it clean; also, the operator should be provided with gloves. The work-piece is usually dropped into a nest

fitted to the tool, and having a passage machined in the bottom through which the compressed air is blown to keep the tool clear of swarf.

It is not necessary to locate the blank from the entire circumference, and in the case of a gear wheel location from about three teeth on each side is sufficient. If the blank is good and the form true, location is more or less automatic when the pressure is applied, owing to the natural equalisation of resistance; this, of course, applies only to concentric articles. Some blanks are struck with two or three ancillary pilot holes which are then "picked up" by pilot pins on the shaving tool. If this

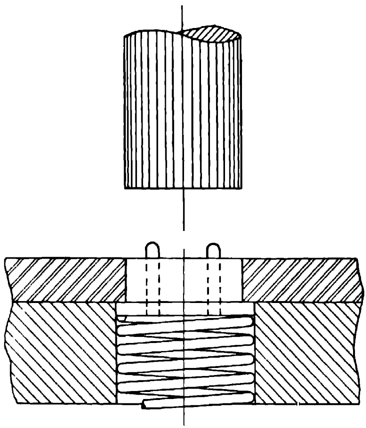


Fig 315.—The use of a spring-loaded platform to return the part to the die face.

method of location is employed, the part does not pass completely through the die but is returned to the die face on a spring-loaded platform (Fig. 315).

It is essential for shaving tools to be made of good-class steel and properly hardened and tempered to retain the edge for shaving the metal. If the blank passes completely through the die, the inside of the opening should be finished with a stone after hardening. A very minute amount of draught is an improvement, but no die clearance is necessary. The punch requires to be a sliding fit in the die, and the alignment should be perfect.

Loop Bending Tools.—Another type of small bending tool which is suitable for use with a fly or hand press is the loop bending tool which is positive and, excepting for a disappearing location, is springless. The construction of the tool is very simple, and if light brass or mild steel is used

as stock, it will form a complete loop, as, for example, on a hinge. It is rigid and stable, and is so designed that it holds the punch towards the material, and the metal towards the tool (Fig. 316). If it is made to limits and the material is up to size, when the punch is being withdrawn the friction will cause the piece-part to be pulled out of the tool. It is possible to use it on a small power press, but extremely dangerous, as are all open tools of this description.

In connection with the foregoing group of operations, the outstanding technical point to be considered is the hardness of the strip or sheet metal, otherwise known as the " temper " of the material. When selecting metal, the properties chosen should be such that the bending operations can be made without fear of any fracture. The principles underlying the bending processes are usually very simple, but in some production factories the machines employed to carry them out are often elaborate and complicated.

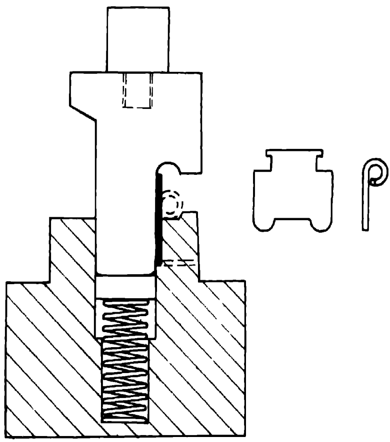


Fig. 316.—Tool for forming loop in one operation.

Drawing and Rolling Strip.—Where long lengths of soft non-ferrous sections are required, they are generally produced by drawing through a die mounted in a drawbench. Heavier sections in iron or steel, however, are passed through a series of suitably-shaped rolls.

Whether certain sections can be produced from the solid by extrusion, or rolled from strip, depends largely upon the dimensions, as these production processes have the usual economic limitations. Where the gauge of metal does not exceed $\frac{1}{16}$ inch, it is usually decided to manufacture from strip.

Springs and kindred articles which are made from hard rolled or drawn strip metal, bent in press tools, should be arranged, if possible, so that the most abrupt bends are at right angles to the grain of metal employed, because it has been found that material can be bent with more certainty opposite to the direction in which it has been rolled, than with that direction. The radius of all bends should be made as large as circumstances will allow, in order to reduce the causes of weakness such as fractures and surface cracks. Much valuable information and data have been compiled

regarding the hardiness and bending properties of certain materials by Straw, Helfrick & Frischrupp (*Amer. Inst. Met. Eng.*) and G. R. Gohn (*Amer. Soc. Test Mat.*, 1936).

Piercing Dies.—The piercing of holes is governed by several factors, which have to be seriously considered where thin metal is concerned. The design of the tool plays a very important part, as also does the hardness of metal to be pierced, but it is generally safe to limit the lowest margin of piercing to a hole of diameter equal to thickness of material. It is quite possible to pierce holes of diameter one-half the stock thickness, in tools specially designed for the purpose, such as compound tools which have already been explained, because the piercing punches are supported all the way down. Moreover, the piercing takes place at the moment of blanking, so that the material is held tightly and rigidly. The length of the thin piercing portion of the punch should be equal to approximately three times the thickness of the stock to be pierced, the remainder of the tool being of larger diameter. This helps towards rigidity and alignment, which are essential with small holes.

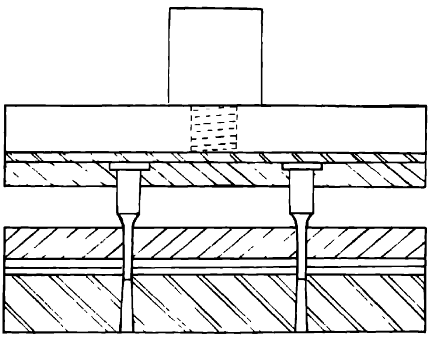


Fig. 317 —A plain standard piercing tool.

The practice adopted by many leading firms is that all holes are pierced if the diameter is not less than one and a half times the gauge of metal, smaller holes than this being drilled. This keeps on the safe side and does away with needless and costly experimenting.

The choice of material for piercing punches is another important matter. Silver steel is used extensively for punches which come within ordinary or safe limits, and if the heat treatment is carried out to the manufacturer's specification, it will do the job admirably. Many steel producers market special material for punches (The Ford Motor Co., Ltd., make their own), and one well-known brand for fine piercings is known as "Van Tapp."

In Fig. 317 is shown an ordinary plain piercing tool. The die is sometimes made solid from cast steel, but often from mild steel with hardened-steel bushes pressed in, and this appears to be simpler and more economical. The amount of die clearance which gives the best results has been found by practical experience to be equal to half as much again as that given to a blanking die, *viz.* one and a half thousandths (·0015 inch) for every

thirty thousandths (·030 inch) thickness of stock. Punches are sometimes made parallel, a tight fit in the punch plate and just burred over at the top end; in such cases a hardened backing plate is fitted between the two plates, to avoid the punch digging into the punch pad. In other instances the punches are made in steps with a head, as in the illustration, and are usually ground to size after hardening. One very important fact should be carefully noted, *i.e.* that end of the punch which pierces the material should be perfectly parallel, as if it is a fraction larger at the bottom end, in the action of stripping the punch will be dragged off.

If the punch and die are properly constructed with the correct amount of die clearance, the hole will always conform to the size of the punch; but when the die becomes worn and the hole in it becomes larger, then the punch, instead of being able to pierce a clean hole, is allowed to force a certain amount of metal down between it and the die, which will then cause a distorted and larger hole. In some cases, failure to pierce hard and heavy material is due to buckling of the punches, especially when these are not hardened all the way down.

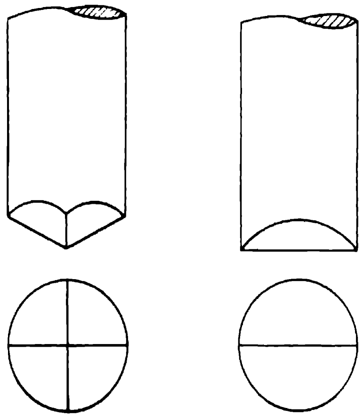


Fig. 318.—Piercing punches constructed with shear for heavy material

It is a common practice when punching holes in heavy material, to alter the shape of the punch so as to form a shear (Fig. 318). This answers two valuable purposes: first, it does not require such a heavy blow to force the punch through the material, and second, the punch has a tendency to centralise, instead of being forced out of alignment to the die by distortion. Some designers favour a wedge shape, others prefer three flat sides forming a pyramid, or four flat sides, this being termed "sugar loaf."

Great trouble is experienced at times by the pierced slugs, which, instead of passing right through the die, have a tendency to return out of the die face. This does not usually occur when a die is new, but immediately it begins to show any signs of wear. There are several distinct reasons for this fault, which only experience can teach, the first being that the die or punch may be magnetic, as a result of being in contact with the grinding machine; secondly, the inside taper of the die may have a slight bump in it, causing an uneven piling of the slugs as they pass down. This, with

the aid of lubrication, tends to form an air lock, thus returning the top slugs to the surface. Another reason is that the die may not be sufficiently hard so that it very soon becomes *bell mouthed*, and this will always be a source of trouble. A further reason which occurs in pierce and blank tools, mostly of the washer variety, is that the amount of metal forming the wall cannot stand up to the blanking operation, and collapses on the hole, making the piece-part diameter less than the die opening, thereby allowing them to return. Although in the modern practice of tool-making the die draught is carried right to the die face, where this trouble is liable to occur it is an advantage to leave a "land," or parallel part to the die opening, of about one-fourth the depth (Fig. 319).

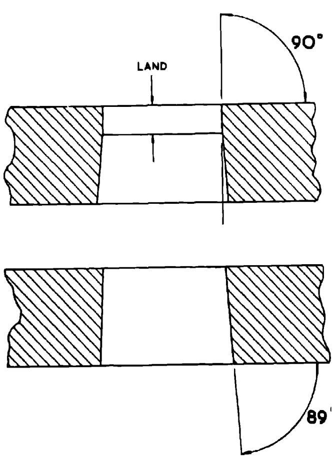


Fig. 319.—Example of a die showing "land"

Quantity Piercing.—Where very large quantities of any one component have to be pierced, owing to the fact that punches and die must always have sharp edges, it obviously tends to hold up production if the tool must be taken down, re-ground, and then re-set in the press again. In several factories this difficulty has been overcome by designing a multiple piercing tool, to do a single piercing job. This may appear a rather costly procedure, but it has proved very economical in the long run, and reduces the "hold-up" time very considerably. Actually, a tool is constructed which is in fact a group of facsimile tools, but all made in one, so that in operation the work is merely distributed between all the punches until the whole of them require re-grinding.

Locations.—It is very essential when piercing holes in small components that the locations should be such that they definitely position the piece-part. With small piercing tools these usually take the form of a nest cut out of a thin plate, which accepts the blank easily, but does not allow any movement. This, although necessary, proves at times to be a great disadvantage, as the component, after having been pierced and stripped off the punches, drops back into the location plate. This can be successfully overcome by fitting a flat spring "knock-out." This little accessory is screwed to the back of the piercing tool, and is composed of a piece of flat spring with a steel pin riveted into one end (Fig. 320). When the piercing has been completed and the punches are ascending in the act of stripping

but before reaching the stripper plate, the piece-part comes into contact with the "knock-out," which is forced back against the spring pressure, until the punches are totally withdrawn, when the component will fly out of the tool.

When piercing or stripping a piece-part which has already been bent or formed, it is very important that the die and also the stripper should conform to the contour of the component, to obviate the possibility of the pressure, when exerted, causing distortion. It often occurs that holes have to be pierced in the outer rim of a shell. If the die is made in the form of a horizontal mandrel, with the die opening vertical or at right angles, the punch must be shaped to conform to the outer radius of the part being pierced, or, in other words, to the radius of the die plus the gauge of metal.

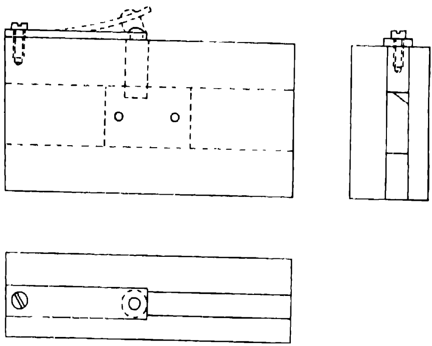


Fig. 320.—Piercing tool with a spring "knock-out"

In very heavy piercing, the base of the punch is liable to expand and burr up; it then becomes a potential source of danger, tending to burst the casting; moreover, it is extremely difficult to remove for renewal. This trouble is forestalled by having the bottom end of the punch smaller in diameter than the hole to receive it, retaining it in position by means of a split collar, or by a ball as shown in Fig. 321.

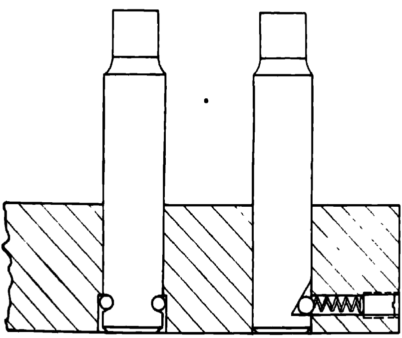


Fig. 321.—Two methods of retaining punches.

Pierce-and-crop Tool.—A variation of the "pierce-and-blank" and the "pierce-and-form" tools is the "pierce-and-crop" type, which provides a good economical method of producing articles required in large quantities. There may be subsequent operations to the pierce-part, and indeed there usually is, such as forming or bending.

A typical part to be produced is shown in Fig. 322, and the tool to produce it is seen in Fig. 323. It will be noted that the stop can be extended, and is easily altered to produce a part to the length required. Many of these tools are made "open," *i.e.* without a stripper plate, but in such cases the punch must be made wider, so that a gap can be ground in it, forming two lugs which enter the die first to maintain alignment. This latter method makes the tool a little cheaper to produce because of the absence of a stripper plate, but it is considered that all "open tools" are dangerous and considerably more liable to cause injury to the operator, as it is possible to put a finger inadvertently between the punch and die. On the other hand, if a stripper plate is fitted, the stroke of the press is so adjusted that the punch is always entered in the stripper plate, making it impossible to push anything under the punch except through the groove provided as a guide for the material strip.

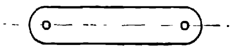


Fig. 322.—The component produced by the tool shown in Fig. 323.

Underneath the die shown in Fig. 323, part of the base is machined at 15° so that when the part is cropped off it automatically falls away, allowing the strip material to be pushed up to the stop in readiness for the next stroke. Tools of this design are sometimes made with a series of interchangeable guide plates so that they can be altered to suit the width of the component required. The radius on the strip end then becomes slightly eccentric to the hole, but usually the designers can compensate for this. As with the ordinary "follow through" tool, the die requires draught or "backing" off to a minimum of 1° inclusive, this applying also to the piercing holes.

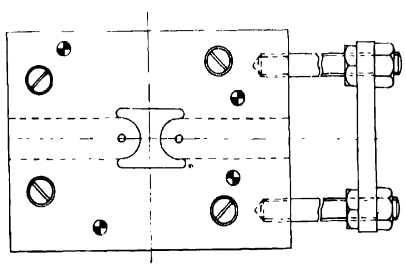


Fig. 323.—A simple "pierce-and-crop" tool suitable for producing large quantities.

If the tool is for use with material that may vary in thickness, it is advisable to calculate the die clearance to suit a thickness midway between the two extremes. It will be noted that the "first off," or the first piece cropped off, is "scrap," as the end will not have a radius or a hole: thus for the first stroke the experienced operator will not feed the strip up to the stop, but only just past the cropping punch.

Notching Tools.—This is merely another name given to blanking or piercing dies, the only difference being that the piece that is blanked or pierced out becomes the scrap, and the other part becomes the product. In the piece-part shown in Fig. 324, the action is exactly the same as in a blanking tool. There is no side stress, and the punch directly severs the

strip and makes two components at a blow, excepting the first one, the position of the material being usually governed by a finger stop. A certain amount of metal is wasted to allow the punch to cut on both sides, otherwise the punch would be thrown over and, in so doing, damage the die.

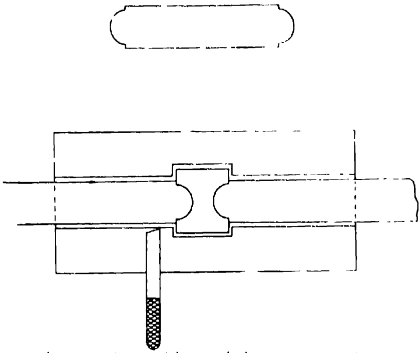


Fig. 324.—Strip-notching tool, showing component.

Where a notching punch only cuts on one part of its face, the other side or back must be supported either by having the punch ground away, so that one part of the punch enters in advance of the other, or by having a step on the die face to act as a stop to the punch when it strikes the material. Both methods of support are frequently used in the construction of these small tools, but the former is usually preferred as it mostly works better. The punch is made to fit the die as in a blanking tool, and after hardening and tempering, one part of the punch is ground away, leaving a leg. On a press with ½-inch stroke, this is left ⅝ inch long so that just over ⅛ inch is continually left in the die; the stock is then fed back to this, which then acts as a stop (Fig. 325). In the cutting up of material, when rectangular pieces are required to a definite size, or within ·002 inch, they are usually blanked out. Unfortunately this method causes a certain amount of metal to be wasted between each blank and also a margin each side. For this particular job,

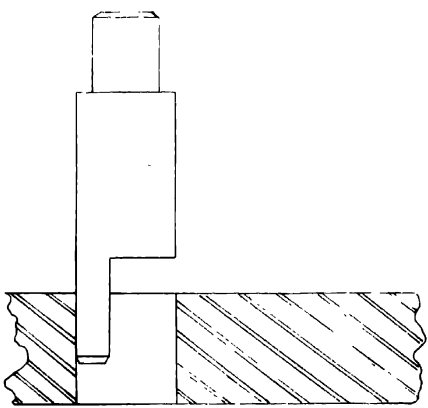


Fig. 325.—Notching tool—supported punch type.

a notching tool can be used to great advantage with very little waste, excepting the narrow strip on each side:

Embossing Dies.—Coining and embossing are very similar in many respects. Coining as a method of fabrication is now being more extensively used, as engineers have discovered that a great deal of machining can be eliminated by the efficient use of coining dies. These require special presses, as the pressure needed is considerably more than in ordinary press operation. In many examples of motor components, rough drop forgings are produced, and instead of being machined as previously, they are brought to perfection by a series of coining operations with the requisite dies. The pressure required is mainly governed by the depth of embossing, and also by the temper and resistance of the material employed. In some instances pressures equal to 100 tons per square inch are required in order to obtain sufficiently sharp impressions. For the production of coins, latch keys, etc., blanks are usually struck with a standard blanking tool from the strip, these are then annealed and afterwards cleaned before being fed into the embossing tool.

Embossing dies are mostly made by the hobbing process as in the case of small tools, and by the die-sinking method in the case of the larger sizes. The type of hob employed is usually fairly easy to make because the pattern stands out in bold relief. Hobs are made from good-quality tool steel, the face being turned and polished and afterwards coloured with a material which allows the embossing design to be traced upon it. The material is then milled away round the outer edge in the die-sinking machine, until only the pattern is left. The raised surface is now finished off with chisels, files, and graving tools, and afterwards hardened and tempered. The die-block is marked off in the same way, the pattern being sunk in to the desired depth by milling tools. The top tool is now located in the recessed portion and pressed in by the hydraulic ram or under the drop hammer. Where the quantity of parts to be produced allows the expenditure, the hob is retained as a master, otherwise it is used as the top tool and the recessing of the female die, opened up, to allow for the metal thickness, before being hardened and tempered.

Embossing dies are essentially to form a pattern in relief, such as letters or an ornamental design on the surface of metal and other materials. Embossing is entirely different from forming, as the impressions to be transferred are mostly very shallow, whereas a forming die is to produce the necessary shape to the component. The lettering, trade marks, decorative designs on all kinds of sheet metal, boxes, cans, domestic utensils, etc., are produced with embossing dies. With a coining die, the impression is usually recessed on both top and bottom tool, but with an embossing die it is composed of male and female members. Dies are often designed to blank, form, and emboss in one operation, and can be double action, triple action, and multiple action, according to the job and presses available. There is local stretching, as well as compression of the material in all embossing operations, and this must be allowed for. The

amount of stretching depends on the size and height of the raised pattern, and on occasions much experimenting has to be done to get the metal to accept the design without splitting or cracking ; every problem has its limitations, and the design must be considered in conjunction with the material to be embossed. Sharp corners should be avoided as far as possible, except where the flow of metal is in one line, so that there is no clashing in the direction of stretch of the material. Coining operations are usually performed in knuckle-joint presses, which on account of the class of work they do are often called " coining " presses. The large types are geared and very strong tie rods take the enormous pressures applied. This type of press gives a pressure which can be compared to a squeeze, in contradistinction to other presses which do their job mostly by impact. The steady pressure exerted by the knuckle-joint press enables the metal to flow equally under the punch, and fine intricate embossing is thus made possible, whereas a blow would not give the material an opportunity of entering the delicate engraving on the tool employed.

Indenting Dies.—This type of die is used mostly for forming " pips " or protrusions where needed, such as contact blades on a rotary service joint. They are usually quite simple in construction and manufacture, but dependent on the sharpness of the embossed protrusion, so the tool is laid out with this end in view. Often it is very difficult to produce a " pip " high enough to do the job for which it is required without cracks occurring, the material employed being the prominent factor. This, in the majority of cases, is phosphor bronze, which must not be annealed. Should the material be brass or mild steel, the matter is simplified. Only by experimenting can a good definite result be obtained, and it is usually best to form the " pip " uppermost by a series of hollow punches (Fig. 326). After it has been discovered how much metal is drawn in by forming the protrusion, then this amount can be added to the width of the material, and the surplus remaining on the other part of strip finally cleared away.

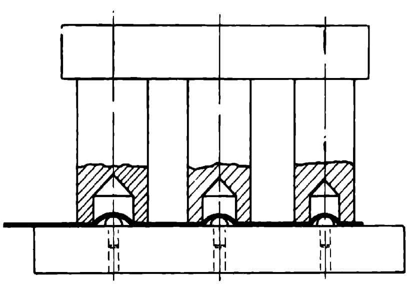


Fig 326.—Indenting tool—forming "pip."

Indenting Tools.—It often occurs that small holes are required in components or sheet metal that are far beyond the margin of piercing possibilities and hence they must be drilled. Many firms employ professional " markers off " who are usually quite rapid and trustworthy, especially where repetition work is concerned, but other firms prefer to indent or

"spot" the centres of the holes in the various productions that are too thick or hard to be pierced by means of a press. It is quite a sound idea and brings the holes to within tolerable limits. The tool consists of punches ground to a point at about 60°, and mounted in a punch-holder to precision limits. A bolster is also made with a nest and other forms of location, on which the component to be indented can sit easily and flat. The tool, which is mostly used in a fly press, is adjusted so that the pointed punches enter the material from five to twenty thousandths, forming indentations which are then followed up with the requisite size drill.

Necking Tools.—The use of spinning tools is steadily declining, although there are many manufacturers who refuse entirely to dispense with this method of fabrication. It is now only adopted by modern manufacturers for very large jobs which cannot be placed under standard presses, although in some remote cases it is used in conjunction with a press, by constructing a tool to draw sufficient metal, probably in steps or corrugations, and this is afterwards spun to the finished shape, on a wooden former, revolved by a machine similar to a lathe. Some very large light reflectors, mostly for export, are manufactured in this manner, but actually the amount of spinning done at present is very little. A few years ago if an article had to be "necked" it would invariably have been done by spinning, but using the modern methods it would undoubtedly be completed with a press tool in a considerably shorter time.

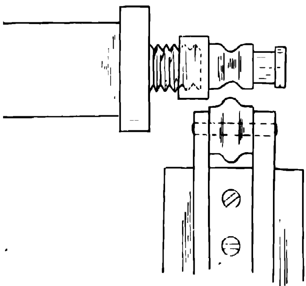


FIG. 327.—An example of spinning tool for necking

Necking is often found in the construction of electrical fittings that have to be retained in porcelain. A neck is formed in the cast product which fits round and locks both together. If this necking, which has to be continuous, is formed by the spinning method, the part is first "drawn up," in a sequence of operations, to the developed size, *i.e.* a certain quantity of the material is left for the necking operation, which will have the effect of shortening the component. The piece-part is now rotated at high speed on a mandrel, which is made from hardened tool steel to the required shape, and a former, carried on ball bearings, is forced up against it until the depth needed is produced (Fig. 327). Contrary to the design of some small spinning tools with knurled driving rings, the component requires nothing to drive it, only the pressure of the metal to metal. Stops are fitted to the machines operating these tools, to avoid further pressure after the necessary form is produced, and useless thinning of the metal is thus avoided.

Necking by Forming.—In modern production, the article referred to above would be "necked" after forming in a press tool, and it will be gathered from Fig. 328 how this tool is constructed. The central boss or forming die is usually made from medium-quality cast steel, afterwards hardened, and is constructed in two sections to enable the component to be removed after forming. The punch, which is also made in two halves, fitting inside the die, with the necessary clearance for the metal, is also made of hardened cast steel. The top portion, which can be called the "driver," and the bottom bolster are constructed from mild steel. The spring plunger which will be noticed protruding from the driver is to hold the top portion of the die down as a resistance against the effort of the punch to force the two apart. The pressure required is considerable, and has to be adjusted to suit the component. After the press is operated and the neck formed, the component is pulled off with the upper portion of the die inside, and this is afterwards removed through the top and replaced on the tool. Two soft rubber inserts will be observed, the purpose of which is to force the two halves of the punch apart, although springs could of course be used. A slow-moving press is the most suitable for this class of tool, as pressure is more essential than impact.

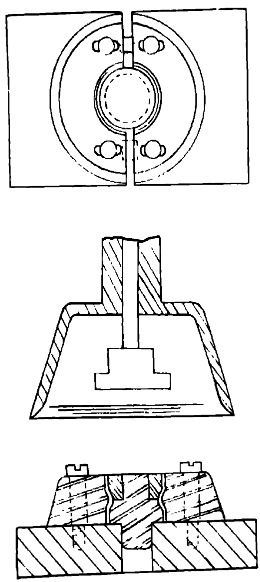


Fig 328.—Press tool for necking, "splits" type

Dies for Tapering.—In the production of tapered or conical shapes, it is sometimes necessary to employ quite different tactics to those which are used for the fabrication of shells of cylindrical form. The depth of the component in conjunction with the diameter and also the taper required are of considerable importance according to the class of work being produced. It is quite possible, in many instances, to form a shallow tapering piece-part from a flat blank in a single operation; on the other hand, many apparently simple tapering forms can only be produced by a sequence of operations. The form given to any component in a primary operation is always governed by the final shape that the object will eventually become. Conical shapes formed directly from a flat blank are very apt to crinkle or fracture before the part can reach the final shape required. Experience is very helpful in determining where and how much surplus material is beneficial in forming the shape

desired, without unnecessarily increasing the resistance. Nothing is really so valuable as a comprehensive study of methods which have already proved successful. In many instances, with the forming of conical or tapering shells with open ends, it is necessary to leave one temporarily closed as a resistance against the final drawing process, also to avoid splitting at the smallest diameter which might possibly occur. With a conical-shaped punch and die, when the necessary pressure is exerted by the press, the action which takes place is to spew the metal out, or force it down to the largest diameter. After this component has been formed, the bottom is "knocked out" with a piercing tool made for the purpose. The final operation can be accomplished in the lathe with a box cutter, dependent at what angle the bottom edge of the metal requires to be. A cup is drawn in two operations by similar tools to those shown in previous sketches, and the final forming is completed in the tool shown in Fig. 329.

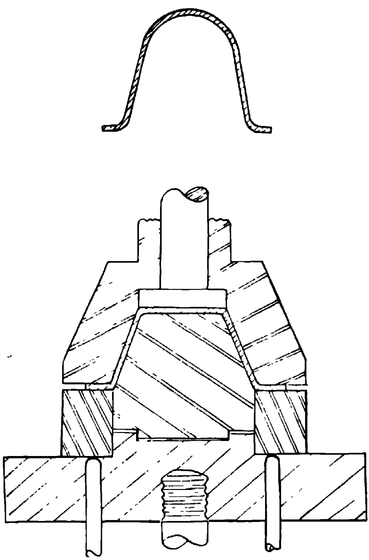


Fig 329.—Cone-forming tool—final draw.

Tapering metal under a press is a very difficult process, requiring special heavy-duty machines to cope with it. It is a procedure that is not often adopted, and its applications are strictly limited. When a shell is drawn up and it is required that the metal forming the walls shall be tapered, it is invariably done in a capstan lathe. To purchase material already tapered by extrusion and rolling offers so many advantages that it would be extremely uneconomical to attempt to taper metal by direct vertical pressure. The copper segments which are a component part of the commutator of an electric motor are "blanked out" from the strip metal, which has been previously tapered by extrusion. The firms that produce these articles require such enormous quantities, and in addition the friction set up by the copper on the tool makes it necessary for the die to be composed of special-quality high-speed steel. One firm has these special dies made from carbide steel at a heavy cost, but presumably this is economical in the long run.

Swaging and heading dies are in constant use throughout the engineering production world. Swaging very small articles, such as flattening a piece of round or square wire and then cropping it to a desired shape, is a process performed in very simple tools and needs little explanation.

Heading Dies.—These have, in the past, caused considerable trouble, owing to the difficulty in producing a steel to stand up to the heavy strain, but this has been successfully overcome and steel manufacturers are now able to offer special material for these tools. A heading die is a very simple affair, consisting of a hole in a piece of steel which forms the die, and a flat punch which descends and flattens the end of the material from which the bolt or pin is being made, this being usually round mild-steel rod projecting from the die face, an equivalent amount to form the bolt head. The pressure needed to cause the metal to flow under the punch is obviously considerable, but this stress has now been greatly reduced by having a small hole drilled in the end of the rod which is to form the head. This hole is usually drilled in the capstan machine to a predetermined depth by development (Fig. 330).

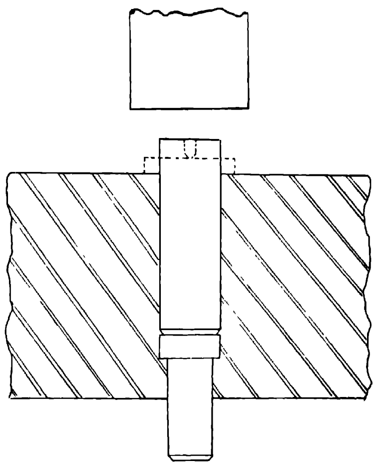


Fig 330.—Heading die with component in position

Lettering and Stamping.—This is a job that is easily completed with the valuable aid of a fly or hand press in those establishments where quantities of a given fabrication have to be stamped with a number and "country of origin." Sometimes the lettering stamp is made in one piece by an engraver, in other cases a group of single stamps is used, held in a mild-steel stock, specially made for the purpose. The anvil or bed upon which the component is laid for stamping must conform to the contour of that part which is to receive the lettering, otherwise distortion will occur. Delicacy in setting the press is essential in order to obtain just the depth needed, as if the letters or figures are allowed to enter the metal too deeply, it will cause spreading. Often when a component requires to be stamped deeply, this is done before the final forming operation, so that any distortion is then rectified. In very large factories,

where high-speed production is employed, elaborate special machines are used for this class of work, often hopper or band fed.

Tools for Wire Forming.—The majority of wire-forming tools are made on the cam principle. They are usually more simple to design than ordinary bending tools, especially if they are to form spring wire, as the wire can often be forced over a punch which forms a loop, and then is merely "stripped off," with the knowledge that the springiness of the material will help it to resume the original shape produced. Fig. 331 is a sketch of a simple tool to form a wire spring with a loop. The pieces of spring wire are first cut off to length and laid in a groove by the operator, who handles them with a pair of long-nosed pliers. When the tool descends, the pressure pad, which is fitted with very light springs, comes to rest on the two forming punches in which the groove is machined. Continuing the descent, the forming punch forces the wire down, and at this moment the cams come into action, moving inwards towards the neck of the punch, thus forming the loop. Owing to the fact that the end of the punch is made spherical, the wire loop usually slips off sideways at the upward movement of the tool, but should it not do so, it is just pulled off by the operator.

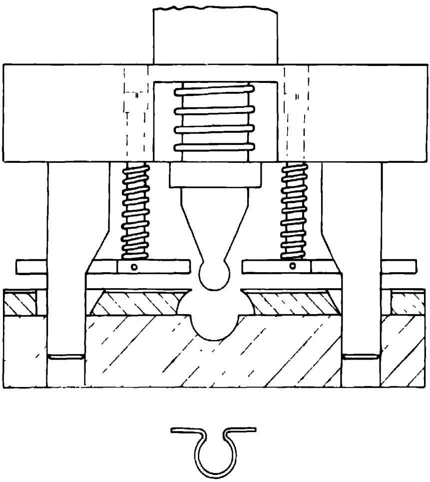


Fig. 331.—Forming tool for wire spring

As a further example of wire forming, a simple tool to form a "U" or staple may be considered. The pressure pad, which in a case of this description is best made from mild steel carburised and case-hardened, has a recessed slot machined in it to receive the wire between two small pin stops pressed in. The punch and die, made from cast steel, are hardened and tempered. In operation, the punch descends on to the pressure pad, lightly trapping the wire confined in the groove, and, continuing the movement, forms it over the punch; the pressure pad, moving down supported by the springs, maintains the wire from twisting. It only requires a little thought combined with a knowledge of metal forming to design a dependable form of simple press tool.

Trimming Tool.—There are possibly more varied designs of trimming tool than of any other form of press tool. Nothing in this line is really standardised, as for each trimming job there are so many different ways in which it could be accomplished with probably the same result. The only thing to be considered is the type of tool which will do the job in the most economical manner. One method by which a rectangular box is trimmed has already been dealt with (Chapter 13, Fig. 286), *i.e.* a trimming tool made on the blanking-tool principle. This method should always be used whenever possible, as the tool is simple and durable. It is, however, only applicable when a box has been drawn by the double-action method and the rim, which was held by the pressure pad, is retained at right angles. This is not always the case, and a rectangular box may have passed right through a die in its final stage, which makes it necessary to alter the design for trimming the top rough edge.

The tool shown in Fig. 332 is admirably suited for a trim of this description. It is completed in two operations by turning the box round to 90°. The first operation trims off considerably more than the second, but this, it will be observed, is to retain balance. The tool is constructed on the pillar principle, which is essential to absorb and counteract the side stress, which in all cropping operations is considerable. Trimming tools of this type are capable of prolonged action and extended life, and if sufficient steel is left on for regrinding, this can be done over and over again. The upper cutting steel is ground on the vertical face and the lower tool is ground on the horizontal plane. The type of tool already outlined can also be used for trimming cylindrical fabrications, but it is usual to anneal the top edge before doing so, as this often becomes hard and fragile by the previous drawing operations.

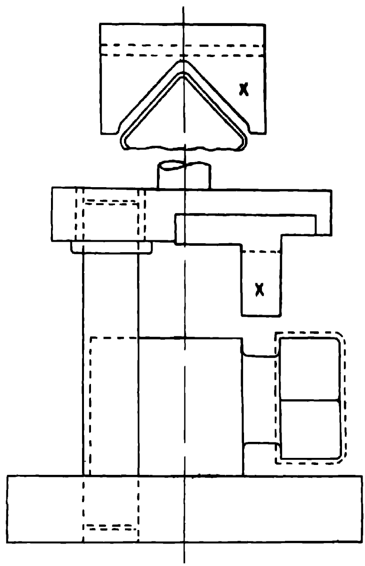


Fig. 332.—Box-trimming tool component in position.

Trimming for Location.—When stock can be procured of the required

width for blanking one or two rows of parts in a " follow tool." this type of tool is often fitted with two or more piercing punches owing to the difficulty in maintaining precision location. Pilots are then fitted on to the punches in other parts of the tool to " pick up " any error which may occur in the feeding of the material, an accumulation of which, if allowed to run on without balancing, would soon cause double-blanking, and many scrap piece-parts. Another method which is employed to effect balance is by having the stock strip oversize and the tool fitted with trimming punches. These punches are usually placed one on either side, and enter the material in advance of the remaining punches, thus maintaining it

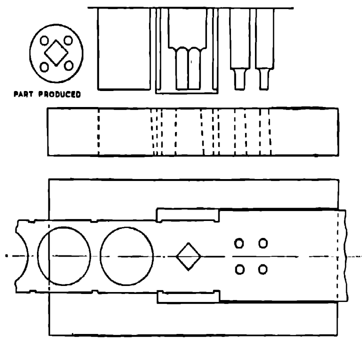


Fig 333.--Press tool fitted with trimming punches as a means of locating strip

a rigid state when the other part of the tool strikes. It also serves another purpose, *i.e.* the trimming is done in steps along the edge of the material, and this acts as a stop, since each movement comes into contact with a protrusion on the die face which is provided for that purpose (Fig. 333).

Another variation of this principle is to have small piercing punches fitted to the tool which make small holes all the way along the strip of material being worked, as in a cinematograph film ; pilot pins are also fitted which enter into these holes at a successive stage, rectifying any error occurring in the sequence of operations. It will be realised that some means of balancing location must be incorporated in all tools of a progressive class, as any error, however small, is accumulative.

With an ordinary piercing and blanking tool with the pilot fitted to the blanking punch to " pick up " in one or more holes needed in the component being made, it is so arranged that the pilot or pilots on entering pull the material back away from the stop approximately five to ten thousandths, as, if the reverse happened, jamming and distortion would occur.

CHAPTER 15

DIE-MAKING

WITHIN the last twenty years, the use of dies for the production of articles from sheet metal has expanded enormously. Vast quantities of parts have to be produced with great rapidity by these dies, extreme precision being essential.

There is practically no limit to the scope of modern tool-rooms in their capacity for constructing press tools capable of performing the many and varied operations necessary to produce reliable and interchangeable parts in the press. The motor-car engine and body, the wireless set, the telephone, and indeed all branches of engineering production, are to-day largely dependent upon parts produced by the press tool.

The size and shape of the punch and die are usually determined by the form of the product, but where it is at all possible these should be so proportioned that there is a minimum resistance to the flow of material being used.

It is usually a case of the application of the principle of " trial and error " to obtain the most satisfactory shape of punch and die for the production of the article required. Theoretical size in development can never be strictly adhered to because of the thickness or gauge of the material and its hardness, while slight variations in the allowances made in the designing of the press tool will also affect the final result. By a system of compiling data from all previous jobs, some tool-designing offices do, however, get very near to determining definitely the necessary size of blanks before these are finally developed in the tool-room. Where there is good collaboration between the die-room and the drawing-office the problems of design are made much easier. The theoretically developed size, calculated to three places of decimals, is entered on the tool drawing, but always a query mark is added. The tool-maker is then expected to make up trial pieces and bend them or form them to the required shape, making notes as he progresses, and when finally he arrives at the definite dimensions, he makes an alteration to the theoretical figure on the print of the tool drawing. When tools are completed, the information is passed to the records department, the tool-room print being compared and adjusted to the original drawing. Thus is obtained the practical data to which the job is worked.

The improvement in the quality of good-class tool steel has done much to minimise the difficulty experienced in the manufacture of intricate shapes, but it does not necessarily follow that all press tools are made

from hardened steel; indeed, this is far from being the case. Many firms, for the manufacture of brass pressings, and also pressings in mild steel, make a soft die and a hardened punch, while in the case of boxes and similar articles requiring the working of very thin tinplate, the die is made hard and the punch remains soft.

It is a very difficult matter to make press tools for the blanking of very thin metal, as immediately the tool becomes worn it will throw up a burr on the material which is being worked. To overcome this difficulty, the usual method adopted is for the soft part of the tool to be "bumped" or "hammered" up, the other portion being re-fitted by shearing. After the shearing process in the tool-room, the punch is not removed again from the die but is passed to the production department, where it is set up in a press and operated, thereby avoiding the possibility of the punch taking up another position relatively to the die upon being reset—which it would invariably do.

Like most other branches of engineering, tool-making has improved from year to year, the war of 1914–1918 giving a great impetus to this particular branch of the industry. The blacksmith was the first tool- and die-maker, as, when he had a repetition job or an article to make of which any quantity was required, he made "top and bottom" tools. These were mostly crude-shaped dies which had been drilled and chiselled out to some semblance of the form required. Metal was then heated in the forge and placed between these dies, which were then struck with the sledge hammer.

Other branches of tool- and die-making were evolved on very much the same lines, until we come to the tool-maker of about thirty or forty years ago. The mechanics employed in those days were undoubtedly experts, as they lacked all the expensive luxuries in the way of precision machinery which is available to-day, and they had to do their very tricky job usually with the aid of a vice, drilling machine, and a few hand tools.

There were at the time very few presses of any description, and small blanks, etc., had to be produced by the same method as that employed by the blacksmith, *viz.* the hammer. Small blanking and piercing tools were made, composed of a die, a punch, and usually two guide strips to locate the material, and also to position the punch. Strips of thin metal were placed between the punch and the die, and a blow given with the hammer, sufficient force being exerted to drive the punch through the material, after which the metal was stripped off and the operation repeated. The men responsible for making these tools were usually very proud of them, and one of the best blanks from the number that was first struck would be fastened on to a card and kept as a sample. It was the usual practice for the mechanic to exhibit these samples as proof of his handicraft when he went after a fresh job.

Up to a very short time ago, the tool-maker's art was represented by a dexterous use of the file, but this has now been superseded and im-

proved upon by one of the most useful of modern tool-room appliances, the filing machine (Figs. 334 and 335).

Filing Machines.—The first of these machines was welcomed as a great boon to the tool-maker, and owing to the ever-increasing demand was quickly followed by better and improved models. The original filing machines did the dual job of filing and sawing out by the use of a vertical reciprocating motion, but the backward movement of the saw was a great disadvantage, and a much-improved type of machine was produced in which the reciprocating saw was replaced by a

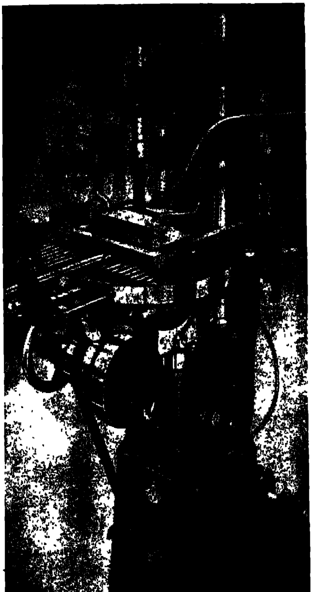


Fig. 334.—Thiel die-filing machine (By permission, E. H. Jones (Machine Tools), Ltd.)

Fig. 335.—The filing machine in operation.

band saw, and to-day a tool-room is hardly complete without both of these valuable machines (Fig. 336).

The production of the enormous quantity of dies which are in use in the factory at the present time was considerably helped along by the steel manufacturers, who were able to produce suitable steel to withstand the heat treatment to which dies have to be subjected in order to harden them sufficiently to resist the incessant hammering to which they are subjected when used in mass production.

Until quite recently, the making of a blanking die possessing a more

or less awkward form was a matter of chance, as there was usually a considerable amount of distortion during the heat-treatment process, but now this anxiety has become almost a thing of the past owing to the production of high-grade carbon steel which will not "shift"—to use the trade term—when it is subjected to the required heat for hardening purposes. This steel is now manufactured and sold in great quantities.

Making Blanking Tools.—The design and construction of dies for blanking tools is governed in the first instance by the area of the blank. A large tool is constructed of a top and bottom bolster, cast iron being used for thin stock, as, for instance, in motor-car body production, while cast steel is used for heavier material. These two bolsters are connected together by four stout steel pillars which are a tight drive-in fit in the lower bolster and a slide fit in the upper bolster, the pillars thus acting as guides. In many instances the upper bolster is fitted with steel or bronze bushes, thereby reducing the friction as it slides up and down the pillars, and at the same time facilitating renewal after wear has occurred. But many large die-rooms just bore through the cast iron, this being found quite suitable, especially if the design of the article being produced is continually being changed, necessitating new tools.

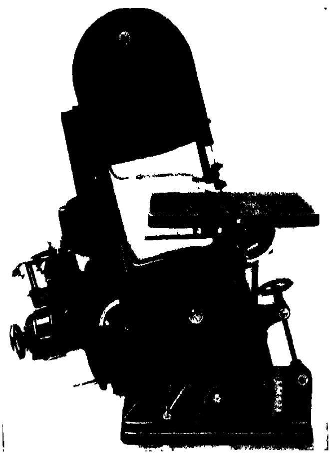


Fig. 330—Thiel band-sawing machine—set up for cutting at an angle (By permission, E H Jones (Machine Tools), Ltd)

The method of manufacture adopted by the makers of the large blanking dies used in the motor-car body and aircraft works throughout the country may now be outlined. The bolsters are usually cast and then roughly machined, after which they are seasoned for two or three months to avoid any distortion which may occur as a result of stresses set up by cooling. They are then re-machined by the planer, a finishing cut being given on both sides of each.

A template, which has been previously developed and tried out, is supplied to the die-maker by the template department, a drawing being also supplied, this being a print taken from a standard sheet with the profile of the template sketched in. In the usual order of procedure, the steels are now prepared for both the punch and the die. In the construction of large dies it is not usual to employ very large pieces of steel, the die being built of small sections, the reason for this being that

large pieces of steel are more apt to distort and warp than small pieces, while heavy material is obviously much more awkward to machine and handle in the heat-treatment process; moreover, if the edge of a large die breaks away when in use, then a small section can be easily replaced at little cost as compared with the cost of replacing the whole die.

In a straightforward blanking tool, second-quality carbon steel is used for the punch and also the die, but should any abrupt protrusions occur, then that section only is composed of the very best-quality tool steel. The blocks of steel generally used for this class of tool are usually about 6 inches long, 4 inches wide, and 4 inches deep, although they can be obtained in smaller sizes to suit any particular job. Larger sizes are, however, seldom employed. The sides, as well as the top and bottom, are now squared up in the shaping machine, and finally they are surface ground on a large rotary grinding machine. In this kind of work, the punch is always the first part of the job attacked by the experienced man. The set of blocks which are to form the punch are now drilled to accommodate Allen screws, and holes are also drilled and then reamered to accept two good stout dowels to each block (Fig. 337).

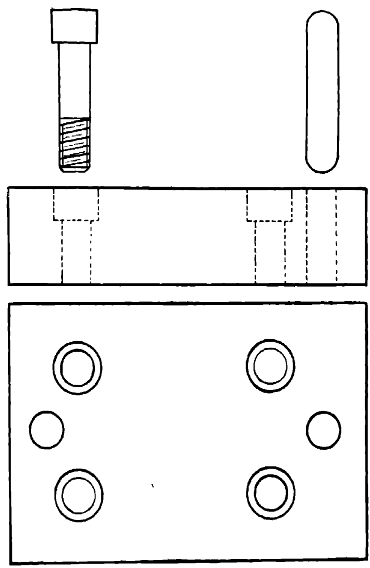


Fig 337.—Prepared die blank

The blocks of steel are now butted together and laid on the upper bolster face in a form which will include the whole of the template profile; a scriber is then run round the inside of the bolt holes only, thus marking their position on the bolster. The holes on the bolster are next centre-popped, drilled, and tapped out to the size of the screws being used. The dowel holes are not transferred until the final assembly and after hardening.

The blocks are now placed in their positions on the face of the bolster and screwed down tightly, after making certain that they are butted snugly together. Some form of colouring material, such as copper

sulphate, or better still, blue lacquer, is then usually rubbed over the surface of the steels, and when this is quite dry, the template is laid on the face and held down very tightly, a thin hardened scriber being run round the edge of the template, thus marking the steels the shape to which they have to be machined (Fig. 338).

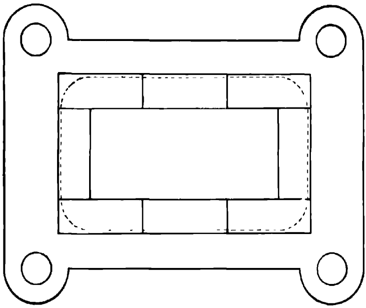


Fig. 338.—Method of marking out the punch profile

In large die-making shops, especially where American methods are used, the modern shaping machine is employed to great advantage, as milling is much slower, and, for that reason, it is also a much more costly operation. The punch steels are now removed from the bolster and machined right down to the scribed line in the shaping machine. A great many shaping-machine operators in this class of shop are very clever, and they prefer to fix the steels in the machine vice with the working lines at the back, so that when the tool finishes the cut, the edge that breaks away is at the bottom and not at the face. If the reverse occurred, of course, the face would need grinding away in order to obtain a square edge. The filing machine now comes into operation, the machining marks being rubbed away, and the steels generally cleaned and squared up ready for the hardening process.

Heat Treatment.—Much has been written regarding the theoretical side of heat-treatment processes as well as of the practical difficulties involved in giving the correct heat treatment to steel, but the practical method which is employed in the majority of the large die-making shops is quite simple and effective for this type of work.

The steels are placed in a muffle furnace and brought to the required temperature, this being usually given by the steel-makers. They are then withdrawn and quenched in clear running water to a "black heat," *i.e.* when the sizzling stops, after which they are laid in oil to cool off. This method of hardening steel has the effect of giving a hard outer surface for cutting, and a soft core to withstand the vibration. The hardened steels are then tested in the hardness-testing machine, after which they are surface ground and the edges just cleaned up with a stone. The steels are now put back on to the bolster face and screwed down tightly into position, after which the dowel holes are transferred right through the bolster by drilling and reamering, and the dowels driven into position. It is important to note that the dowels must not be too tight or the steels may crack.

The same method is now employed with the lower bolster and die steels; but as they are to form the female part of the tool or the die opening, the die steels will slightly overlap on the inside profile of the template, the excess material being eventually machined away (Fig. 339).

Many of the large blanking tools are too heavy to be lifted about by hand, and in good modern die-rooms considerable use is made of the overhead crane. The bolster containing the punch is now lowered either by hand or by crane down on to the four pillars, which have been previously fitted, until the hardened punch steels rest on the soft die steels, when the thin scriber is run round the edge, thus marking the die opening. Now commences the die-shaping operation, and the steels are shaped back until the scribed line is reached.

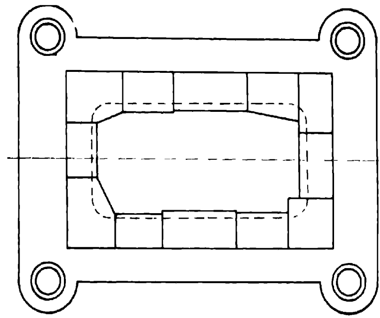


Fig 339.—Method of marking out the die opening.

It now becomes a job for the expert fitter or tool-maker to bed the die steels on to the punch, a tolerance of only ·001 inch being permitted, this being determined with the aid of a feeler blade. This process is usually performed by having the punch bolster replaced on the pillars, and the die steels, after having been smeared with a little paste composed of red lead and oil, are pushed up against it.

The diligent use of the filing machine, the hand file, and the precision square—combined with patience—will eventually accomplish this difficult job, and a perfect fit is obtained between the punch and the die, after which the die steels are ready for hardening in the same manner as were the punch steels before them. After hardening, the die blocks are ground and cleaned up, returned to the bolster, and bolted down. They are then pushed up tight against the punch and feelers inserted all round to check the gap, any necessary adjustment being made by having, perhaps, two or three thousandths ground off one or other of the butt faces until they are a good snug fit. The top tool is then again pulled off, the holes in the die steels are transferred through into the bolster, and the dowels driven into position.

Theoretical die clearances serve a very useful purpose, but not nearly so much notice is taken of them by the practical tool-makers as one would be inclined to believe. For any metal up to and including $\frac{1}{32}$ inch thick, the punch is made a nice slide fit in the die; over and above this amount a good workable allowance is $\frac{1}{1000}$ inch clearance for metal

·034 inch in thickness, the clearance then increasing by ·001 inch for every increase of ·030 inch in the gauge of the stock.

The Parallel Die.—It will be noticed that in the foregoing explanation of the production of a large blanking tool, no mention has been made of die draught or "backing off." It should be noted, however, that with this type of tool, draught is quite unnecessary, as the piece part is ejected by the use of a spring stripper and does not pass right through the die. Where the area of the blank is considerable and the stock being cut up is on the thin side, this type of tool is always employed, as the stripper ejector acts as a pressure pad, being so constructed that when it is extended to its fullest amount by spring pressure, it is just proud of the die face (Fig. 340). Hence, when the punch descends, the stock is trapped between the pressure pad or stripper before the cutting edge of the die comes into action, thereby minimising the possibility of the material being drawn in between the punch and die.

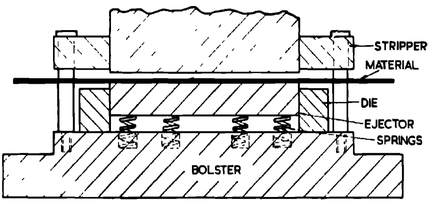


Fig 340 Section of large blanking die as example of construction

The production of strippers for these large tools was formerly a fairly difficult job, but it has been considerably simplified in recent years. A large piece of boiler plate about ¾ inch thick is requisitioned and marked out from the template that was used for the punch and die. The line is then followed round with the oxy-acetylene cutting flame, the inside part, after cleaning up and surface grinding, becoming the pressure-pad ejector, the outer part becoming the stripper plate, which strips the waste sheet which remains on the punch after it has passed through in cutting the blank.

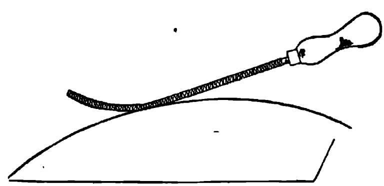


Fig 341 —Bent files for certain jobs.

There are many instances in die-making where it is impossible to use the filing machine, as, for example, in the case of a large drawing punch with many radii and contours. These are usually attacked in a normal shop with the hand and pneumatic chisel, afterwards being finished off to a smooth polished surface with the hand file. It is a difficult matter to file a convex surface with a flat file, but one that has been slightly bent

after heating to a dull red, and then re-hardened, will in many cases be found of great value (Fig. 341).

Automatic Profiling Machines.—In many large modern die-rooms, much use is made of the Keller automatic profiling machine. The accuracy of the work produced on this machine is of such a high standard that the need for hand finishing is almost eliminated. Moreover, several operations may frequently be performed with one set-up, as, for example, a die impression can be cut and the bolt and dowel holes bored accurately in position relatively to the profile. The main feature of this machine is its ability to follow practically any shape or form with the automatic tracer control, this being so sensitive that the shape produced by the cutter is a faithful reproduction of the model or template. This tracer is mounted above the cutter, and is adjusted by micrometer screws. During the operation, the tracer and cutter move in unison, the tracer following the shape of the master form, and the cutter duplicating that shape in the work, this being accomplished by the extremely delicate electrical control of the tracer. There are two distinct operations performed by the tracer control. The first makes use of a profile tracer which guides only the vertical and horizontal movements of the machine, the cutter having already been set before the operation is started, a template being usually employed in this operation (Fig. 342). The tracer point is in continuous contact with the edge of the template as it passes round it, thus guiding the path of the cutter to reproduce its shape accurately on the work. The cutter can be as easily located for a heavy roughing cut as for very fine precision work. The second operation performed by tracer control is in the reproduction of reliefs in three dimensions. Once the machine is set it is fully automatic in operation. The machine controls are set to cause the tracer to cover the entire surface of the master in a series of parallel strokes, either vertical or horizontal, the length of the stroke being adjustable; and at the end of each stroke the machine feeds before commencing the next. The third dimension is controlled by the automatic tracer.

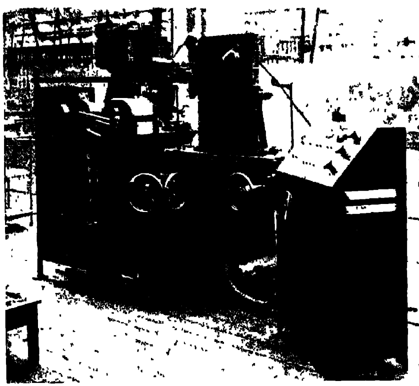


Fig 342 —The Keller automatic tool-room machine. (By permission, Alfred Herbert, Ltd, Coventry)

Directly contact with the model is made, varying degrees of pressure at the tracer point (created by the contours of the subject over which it is passing) cause the machine to travel in unison, consequently faithfully reproducing a complete form of the model. This operation is employed for forming-dies.

In Fig. 343 the Keller automatic profiling machine is shown at work producing a medium-sized blanking tool. The template is seen above and the die blank below, the die steels in this instance being screwed on to the bolster before being mounted on to the machine. A template is made of the die and also the punch with the necessary amount of die clearance, and the accurately machined edges will be noticed in the illustration. After machining, the whole of the die steels—the various parts of which can be also seen in Fig. 343—are taken apart after having been carefully marked, and they are then hardened and tempered The steels are then surface ground on both sides to ensure them being perfectly flat, otherwise when the bolts were drawn down they would be liable to crack.

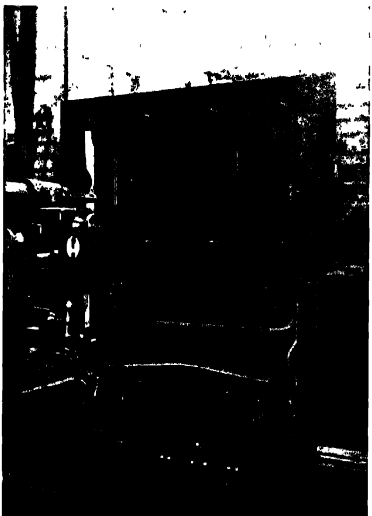


Fig 343 —The Keller. Machining a blanking die

When the top and bottom bolsters are completely assembled with the punch and die steels in position, the punch is entered into the die with very thin packing strips all round, in order to equalise the die clearance in every direction. The complete assembly is then fastened together with clamps, and the holes to accept the pillars are bored right through both top and bottom bolsters; thus assuring perfect alignment.

Precision Holes.—Nothing in engineering practice, especially tool-room work, is of greater importance than the exact alignment of holes. Where great quantities of certain articles have to be produced in order to facilitate assembly and interchangeability, the importance of obtaining absolute precision in the size and position of the various holes cannot be over-estimated. For years the tool-maker of the past struggled with the problem, scheming and inventing gadgets in his endeavour to over-

come the elements making for lack of precision. Spurred on by necessity, many and varied are the inventions that have been placed upon he market during the last few years some costing a few pounds, others costing many hundreds, all of them having as their object the production of holes with absolute precision. Holes can be classified in four groups. In number one are those for which anything will do ; no advice will be needed in the drilling of them. In number two are the holes that require to be somewhere within ·005 inch. Number three includes those that require to be somewhere within ·002 inch, and the remainder those that must be "spot on" or within a tolerance error of ·0005 inch.

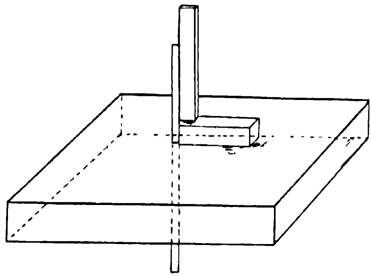


Fig 344 —Checking a pilot hole with set-square

With regard to the second class, these can usually be obtained by first drilling a pilot hole, if care is exercised. After the spot has been carefully marked off, and centre-popped, a small pilot hole is drilled about one-sixth the size of the final hole needed, it being inadvisable to use a drill of less than $\frac{1}{32}$ inch, as it is liable to bend, in which case the hole will run away from the perpendicular. When this pilot hole has been drilled, it should be checked with a mandrel inserted in the hole for position and alignment, any discrepancy being rectified with a small round file before being finally opened out to the required size (Fig. 344).

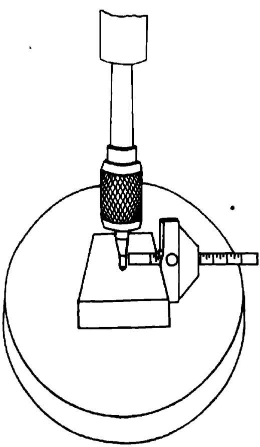


Fig 345 —Method of "spotting" a hole with a depth gauge.

Another method by which holes not requiring a great deal of accuracy can be drilled, particularly applicable to the case of a die, is as follows : Two sides of the die are made square to each other, and some means arranged to fasten the work down on the table of the drilling machine. The holes are then located with a precision depth gauge from the sides of the job, adding half the drill diameter to the reading. In Fig. 345 it will be noted that a centre drill is being used ; this, of course, being equally effective for

" spotting " the hole, which can afterwards be drilled and reamed to size.

For holes in the third class, which have to be accurate to within ·002 inch, different methods are required. Marking off will necessarily play a most important part in the procedure, and the Vernier height gauge can be used to great advantage (Fig. 346). In tool-room language, the positions for these holes will have to be "squared," which means that in addition to the two centre lines crossing at right angles at the exact position of the centre of the hole, four other lines are scribed defining the outer edge of the radius, that is, tangential to the circle, so that when the hole is started and finished it can always be examined for position, with the aid of a good magnifying-glass. If the circumference is within the square, then the hole must be within fairly close limits.

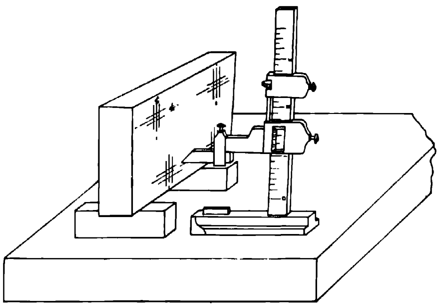


Fig. 346.—Precision holes defined by squares.

An alternative method for boring holes requiring this degree of accuracy, and one which is often preferred, is in the lathe with the use of a " wriggler." Instruments of this type can be purchased, these being made with a knuckle joint, but if one is not available, then a length of silver steel can be used instead, one end being turned to a point which must be concentric to the remainder. After the hole position has been carefully marked off, a good clean centre-pop indent is made at the junction of the two centre lines. The part to be bored is then mounted on the face plate, and lightly clamped. The "wriggler" or the silver-steel rod is held in a small chuck in the tailstock, and the pointed end inserted in the centre-pop mark on the job. An indicator is mounted, usually on the tool box, with the contact finger resting on the wriggler, as close up to the work as possible, as shown in Fig. 347. If the machine is now pulled round, the indicator will register the amount that the hole-to-be is out of position, and adjustment can then be made until the indicator reads " steady," after which the hole is drilled in the usual manner.

There is also the ordinary turner's method of positioning holes with the use of " buttons " ; and another and simpler procedure, somewhat similar to this and adopted by many old-time tool-makers, in which the drilling machine is solely used. This system is known as the " button and block " method, and is extremely useful, being much quicker than setting-up in a lathe. Buttons are made of a size suitable to the holes required, preferably somewhat smaller, having a small clearance hole through the

centre, which must be a very slack fit on the screw being used. The block of cast steel is then trued up and a hole bored, in which the buttons are a good sliding fit. Both the steel block and the buttons should be hardened and tempered. The part to be bored is next roughly marked off, and small holes drilled and tapped to receive the button-

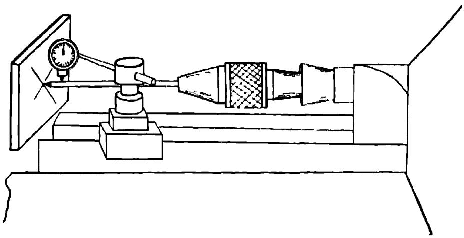


Fig. 347.—Setting up for boring by use of a "wriggler"

retaining screws, which will be in the region of $\frac{3}{16}$ inch or 2 B.A., according to the holes to be bored and the buttons being used. The buttons are now screwed on, and with the aid of a micrometer, or vernier slide gauge, they are located to the exact position and the retaining screw is then tightened (Fig. 348). The block is then slipped over one of the buttons and tightly clamped in position. When all is secure, the screw retaining the button is withdrawn, and the button pulled out of the block. The hole through the block is then transferred through the job by drilling and reaming.

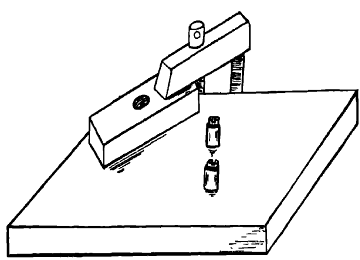


Fig. 348.—"Button and block" method of control when boring holes

The Jigometer.—This was one of the first instruments marketed with a view to overcoming the worries of the tool-maker in drilling holes in the fourth class, *i.e.* those that require to be within very fine limits of error. The jigometer was invented by an old London tradesman, and satisfied at the time a considerable demand. It is quite an efficient instrument, and is in use in several tool-rooms to the present day. It consists of a "trued-up" cast-iron bedplate, with slots running at right angles, in which are retained bolts for holding down the job which has to be drilled. Directly above the plate there is a bracket with a fairly large hole in it to accommodate a series of "slip-in" hardened bushes.

The position of the bracket is controlled by a finely threaded screw, the movement of which in either direction is regulated by a vernier scale graduated to one-thousandth part of an inch. The part to be drilled is fastened on to the bedplate, which is in turn bolted on to the drilling machine. Starting from a datum or zero position, the first hole is drilled to the required size through a bush; the bracket is then moved to the next position, which is accurately located by the adjustment screws and the Vernier scale reading, and another hole drilled, the process being repeated until the job is completed.

The Jig Boring Machine.—There are very few up-to-date tool-rooms at present that are not equipped with a jig boring machine, of which there are several types manufactured by eminent engineering firms. The one illustrated (Fig. 349), the Genevoise machine, which is especially suitable for die work, is made in various sizes with many attachments for enabling awkward jobs to be carried out. It is simple to operate and rapid in action, being capable of boring holes of practically any size in any predetermined location consistently to within ·0001 inch, which for present-day mass-production methods is a very valuable feature.

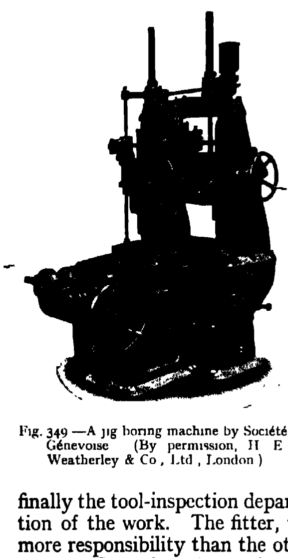
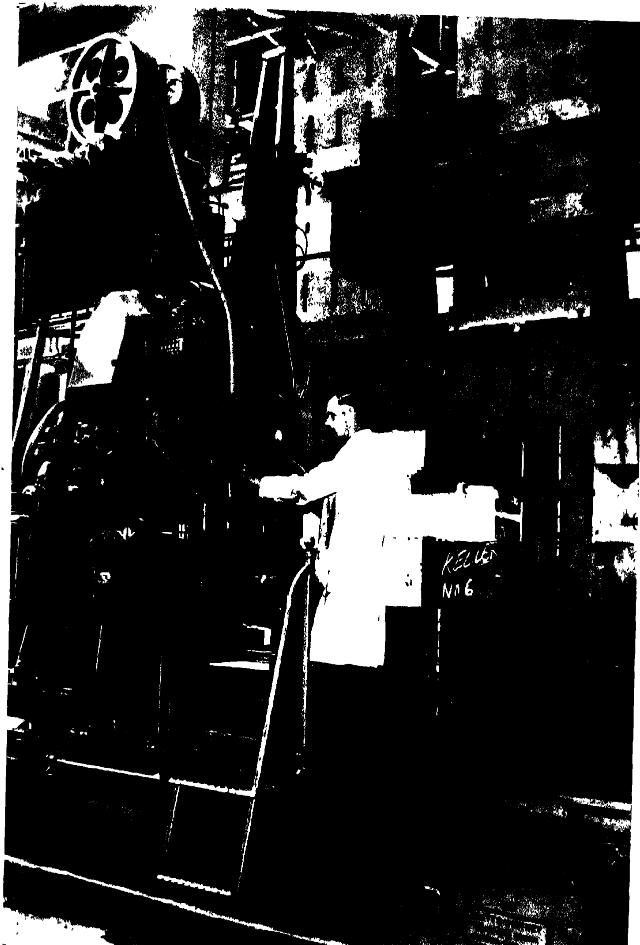


Fig. 349.—A jig boring machine by Société Génevoise. (By permission, H. E. Weatherley & Co., Ltd., London.)

The procedure in the modern tool-room is such that the lot of the tool-maker is far easier than it used to be. Where years ago the onus of responsibility rested on one individual, it is now in all large firms distributed between specialists in each particular department. The shaping section, the milling section, the boring section, the fitting section, the heat-treatment department, the grinding section, and finally the tool-inspection department—each is responsible for its own portion of the work. The fitter, who is really the key man, usually accepts more responsibility than the others, as he has to carry the job to the final stages. Sometimes he receives the material in the rough and hands it out to the various departments for machining, in other cases he receives the component parts of a tool already machined. The first thing to be done in the latter case is to check up the parts to the drawing sizes, this being very important, as each department will only accept responsibility for work done by themselves. In many very large works, such as the Ford Motor Co., this is unnecessary, as an inspection department is incorporated in each section—turning, shaping, milling, boring, grinding, etc.—and the tool-maker does not handle the part until it has been viewed



(Vauxhall Motors, Ltd.)

AUTOMATIC MILLING MACHINE

A Keller automatic milling machine set up for profiling an automobile die. The tracer and two-dimension template are seen at the top.

by that particular inspection department. In most examples of press tools, the die is the piece to concentrate on ; this certainly must be right, and in the case of small- or medium-sized tools it is finished to size, " backed off," hardened, and surface ground first of all. The punch, which has previously been machined roughly to size with about ·005 inch left on for fitting, is then very gently sheared right through the die. There is usually a tendency when shearing under a fly press to go too far ; this must most certainly be avoided, otherwise pieces will be pulled out of the punch, and, as a consequence, this component will have to be scrapped. It is sometimes the practice in certain tool-rooms to give the fitter a piece of steel on which to mark out the punch for machining. This can be accomplished either by setting it up on the surface plate, and marking it off with the vernier height gauge, or by clamping it on to the face of the finished die, and running a thin hardened scriber round the edge.

When the tool has been assembled, the most important problem is the " lining up." It will be realised that a punch entering a die with only one-thousandth of an inch clearance must be in perfect alignment and able to move perpendicularly to the die, otherwise it is useless. The assembled punch unit must be set up on an angle plate, and the indicator run along the punch, or at the very least, carefully checked with the small precision square. The punch is then entered into the die through the stripper plate, as in the action of working, and the top of the tool checked for faults in alignment.

Should any error be noticeable, the dowels holding the stripper plate to the die will have to be withdrawn and the tool adjusted to perfect alignment. The holes are then lapped out to their new position, and new dowels made and fitted to the required size.

Hardening and Tempering.—Quite a large proportion of tool-makers know little or nothing whatever about this branch of the business, the reason being that in the majority of large factories the hardening and tempering department is kept strictly apart, making it unnecessary for the ordinary mechanic to have anything to do with it. But undoubtedly every artisan connected with tool-making should acquire a practical knowledge of the heat treatment of steel so that, if required, he will be able to carry the job right through from the raw material to the final inspection of the finished tool.

One of the chief considerations in heat treatment is the quality of material used, but it may be stated that material of proved qualities purchased from reputable steel manufacturers can always be regarded as being thoroughly reliable. Moreover, the manufacturers supply their own formula for hardening, and if this is adhered to, very little can go wrong, especially if the operator is conversant with the practical technique of heat treatment, so as to avoid the snags or pitfalls, of which there are many. It is always advisable to use a pyrometer, that is, an instrument capable of reading high temperatures, as it is usually found that workmen hardening without using a pyrometer are more inclined to under-heat

than over-heat. This is due to the wish to avoid the greater of the two evils, but it must be emphasised that steel will not harden unless it is brought up to the required temperature.

For use without a pyrometer, the following table serves to indicate the relationship between the colour of the heated material and its temperature :

JUDGING TEMPERATURE BY COLOUR

Cherry red	740° to 770° C
Full red	780° to 820° C.
Bright red	830° to 900° C.
Full bright red	910° to 960° C.
Orange	1,000° C.
Lemon	1,200° C
White	1,250° to 1,300° C

Steel producers say that it is wrong to suppose that high-speed steel cannot be overheated, and undoubtedly they are right, but it should be remembered that it is impossible to overheat with a gas blow-pipe, although it is quite possible with a smith's forge, and this is the only means available for obtaining high temperatures, unless special types of furnaces are employed.

Judging Tempering Temperatures by Colour.—After hardening according to the formula supplied by the firm, the article is cleaned up with a piece of emery cloth and placed on the hot-plate, which is usually arranged on a gas ring, or heated up by some other means until the required colour is obtained, when it is finally quenched.

In hardening cutting tools, common sense shows that the required temper must be at the cutting edge, the remainder of the tool being in all ordinary circumstances softer. For instance, when tempering a reamer, it should be hardened and then laid on the hot-plate, where it is rolled backward and forward to get an equal temper all the way up ; but when hardening and tempering a chisel, where the temper would only be required at the cutting edge, the chisel is first hardened right out ; the shank is then heated, watching the colour-run down to the edge, and when the desired colour is obtained, the whole is finally quenched.

The tempering colours, starting from "light straw," which is round about 230° C., and finishing with "blue," which is somewhere round 300° C., are given in the following table. After the blue temper has been reached the material retains that colour until it is red-hot again.

TEMPERATURE AT TEMPERING COLOURS

Light straw	230° C
Dark straw	240° C
Orange	250° C
Brown	270° C
Blue-brown	285° C
Blue	300° C

TEMPERING TEMPERATURES FOR DIFFERENT TOOLS

Wood saws	300° C.
Screw-drivers	300° C.
Planing cutters	285° C.
Cold chisels	285° C.
Twist drills	270° C.
Punches and dies, taps and chasers, snaps	250° C.
Milling cutters, flat drills, reamers	240° C
Scrapers, lathe tools for brass	230° C.

Silver steel should be heated to cherry red (740° to 770° C.) and quenched in water.

All articles, such as drills, reamers, etc., that have a tendency to distort should be quenched vertically and moved up and down.

For drilling very hard material with small flat drills, heat the drills to the same temperature, and quench in oil, using without tempering. With this method much depends on the heat, and care must be used to bring the steel to its lowest hardening point, otherwise drills will be soft. Very satisfactory and reliable results can be obtained by this method in cases where there is any fear of a tool breaking, such as small drifts, etc.

For very severe work, small tools can be quenched in glycerine, and then tempered to a very pale straw colour (230° C.). As an example of the use of this last method, mention may be made of the very small cutters used in the production of match splints, which, after much experiment, were finally made of silver steel, hardened in a mixture of glycerine and water—one part glycerine and one part water—and then tempering to " brown " (270° C.).

Temper of Steel.—Temper signifies the degree of hardness, which increases with the percentage of carbon contained in the steel, and which has no relation whatever to quality.

The suitability of steel for various purposes depends not only on the quality, but also on the temper or degree of hardness. Consequently, it is advisable when ordering steel to specify the purpose for which it is intended, so as to ensure the most suitable material for the job being supplied. The cost necessarily increases with the quality of steel, as in most things, but the best quality usually pays in the long run, especially where a tool of high endurance is needed, as less frequent re-dressing is required.

Judging Temperature by Colour.—" Cherry red " and " bright red " are rather elastic terms, as no two persons are likely to agree to the temperatures they represent. The table given on the previous page was made after a very careful study of the appearance of steel in average daylight, when heated to these temperatures.

The tempering temperatures given by the steel-makers should be strictly adhered to, and in the absence of a pyrometer it is advisable to experiment first of all by heating pieces of steel to various temperatures, so as to become familiar with the colour that steel assumes at

these temperatures. Further, it should always be borne in mind that heated objects look brighter in a dull light than in a bright light, and vice versa. It is very instructive to harden pieces of steel at various temperatures and then to break them in order to compare the fractures. It will be noticed that the piece breaks the easiest that has been hardened at the highest temperature.

While it is advisable to use a pyrometer, with careful observation and close application a workman can soon become an expert in the hardening and tempering of steels without the assistance of such an instrument. It should also be taken into consideration that even if a pyrometer is used, it only registers the temperature near its end, and unless the furnace is closely watched, there can be a great variation in temperature at different points inside the furnace.

The proper hardening and tempering of steel is an " art " only acquired by constant observation, and the best results can only be achieved by great care in obtaining, as near as possible, the temperatures aimed at, as negligence in any form can only result in poor temper and consequently in a poor tool. In heating all tools, etc., they should be placed as near the centre of the furnace as possible, and the furnace doors should not be left open longer than necessary. When a number of articles are being hardened at one time, they should not be placed in a heap, but a little space should be left between each, as, if they are in a mass, the outside ones cool much quicker than those on the inside. Steel should not be left in the fire or furnace any longer than is necessary to heat uniformly through, and if it is heated in a fire, it is best to gradually heat right through, and then bring up to the required temperature quickly, without undue forcing.

If steel for hardening is heated in an ordinary smith's fire, the blast should not be allowed to blow on the article, and the fire should be as clean and as high as possible. The steel should also be covered in with fire, as the oxygen in air, if allowed to play on the heated steel, causes surface decarburation or softness.

If dies are heated in a smiths forge, the die face should be uppermost, with the face well covered ; moreover, the die should be turned round frequently in order to obtain uniform heating. Over-heating should be avoided, as this decreases the strength of the material, and also causes cracking and warping. Uneven heating causes uneven expansion, which is the primary cause of distortion in hardening. Uniform temperatures prevent varying strains being set up on quenching, and this is the secret of successful hardening. If using a pyrometer, place the end as near as possible to the work being heated, in case the temperature is not even, throughout the furnace.

A magnet is sometimes used for ascertaining if the heat is correct. A small magnet is attached to a brass rod, and when the temperature is reached at which plain carbon steel hardens, it becomes non-magnetic. It should, however, be noted that this only applies to plain carbon steel.

A number of small articles can be effectively hardened at the same time by placing them in a piece of wrought-iron pipe, closing up one end and heating in the smith's fire, which has been built well up round the pipe. It should be remembered that steel, when hardened, corresponds to the highest temperature it has attained, no matter whether it is quenched at the temperature or allowed to cool slightly to the correct temperature.

The impressions of dies, etc., can be protected from oxidation and consequent burning away during the process of hardening, by covering them with a thick paste of linseed or cotton-seed oil and powdered bone. It may be noted also that a small tool does not require as much heat as a larger one, since it cannot absorb so much, and this also applies to tools with teeth.

Quenching.—Whatever is used as a quenching medium, it is important that it should be kept as near as possible at a constant temperature. The following is a list of the liquids used for quenching purposes arranged in order of merit :

1. Sprayed water.
2. Brine.
3. Water.
4. Water with oil on top about 2 inches deep.
5. Warm water about 35° C., or 100° F.
6. Oil.

The following rules should be observed when quenching is being performed : For general hardening purposes using water, the temperature should be 50° to 60° F., and the larger the quantity of water the better. When hardening small tools in oil, in very cold weather, it is advisable that the chill should just be taken off the oil. If using brine, it should be just strong enough to float a raw potato.

Large and intricate articles, as well as dies, should be quenched in water, and when they have become black-hot, quickly plunged in oil, as this relieves the strains, and also minimises the risk of distortion and cracks. Articles with holes should always be quenched with the holes uppermost, as if they are underneath the steam which is generated accumulates in the holes, stopping the quenching medium from entering.

Long slender tools should be quenched in a vertical position, a warm bath being used to obviate distortion. To quench gauges or screwing dies, protect the body, and allow a stream of water to pass through the hole, as this is the most effective way to prevent warping.

The thickest part of the article should enter the bath first, and it is inadvisable to allow the job to drop to the bottom of the bath until it is completely cooled. Since there is always a risk of tools or other articles with holes cracking, any other holes not requiring to be hardened can be filled up with fireclay. What is termed "black heat" is that temperature at which, when the article is being quenched, hissing just ceases. If iron wire filled in with fireclay is put round places not requiring to be hardened, these spots will remain soft.

Flat press tools should be quenched in a vertical position, moving up and down to allow the quenching medium to circulate well, and they should be immediately withdrawn when the temperature has fallen to a "black heat," and allowed to cool off in oil. Never grip a heated article with cold tongs, as this usually results in surface cracks. Steel which has been overheated should be again heated to the correct temperature, and allowed to cool in dry lime, sand, or hot ashes.

Tempering.—For tools which require hardening and tempering throughout, if salt, lead, or oil tempering baths are not available, then the surface of the hardened article should be well cleaned with emery cloth, and tempered on a heated plate, until the desired temper colour is reached. If the plate is heated by gas, the temperature can be better controlled than otherwise.

The articles to be tempered should be placed face uppermost, so that the heat runs from back to front. If tools having fine projections are being tempered, a little oil should be smeared on the projections two or three times, as this will prevent such parts being heated to a greater extent than the other portions.

Tools which only require to be hard at the cutting edge, such as chisels, drills, and the like, should have the cutting edge quenched about $\frac{1}{2}$ to $1\frac{1}{2}$ inches up, the article being moved about slightly to avoid a sharp line; the edge is then quickly cleaned up with emery, or other means, and the heat in the body of the tool allowed to run down, until the cutting edge assumes the colour required, when the article is then cooled right off.

High-speed steel is heated gradually to a full bright red (900° C.), and then quickly to a white heat, 1,250° C., being then immediately cooled off in a cold blast, or allowed to cool to a dull red, after which it is quenched in oil.

Annealing.—The most effective way of annealing small tools is to place the articles in an iron box, preferably lined with fireclay, the lid being also filled round the crack with fireclay, to exclude air. The box is then heated up to the necessary temperature, allowing the heat to penetrate right through, after which it is allowed to cool down as slowly as possible. The vacant spaces in the box can perhaps be better filled with charcoal, lime, or sand, and a little resin placed in the box has a good effect.

Case-hardening.—Articles to be case-hardened require to be placed in air-tight boxes, and packed with a good carburising material, the edges of the lids being luted with fireclay, to make the boxes air-tight. The bottom of the box is first covered with a layer of carburising mixture, then a row of articles to be case-hardened, each a little distance apart, is placed in position, another layer of mixture is added, then more articles, and then so on until the box is filled.

The box is then heated up to a temperature of 850° to 900° C., and allowed to remain at that temperature for four to eight hours, according

to the depth of hardening required. It is then allowed to cool slowly. The box is then unpacked, and the articles re-heated and quenched in water or oil. The use of water gives a harder surface, but with oil the risk of distortion is lessened.

Wood charcoal and barium carbonate, 60 parts charcoal and 40 parts carbonate, make a splendid case-hardening media, 20% fresh mixture being added each time it is used.

A Few Practical Hints.—When making a chisel or any tool that has to be subjected to hammering, heat the shank end first and cool in oil; then when the cutting end is being heated for hardening and tempering the shank will remain hard enough to withstand the shock of the hammer blow without burring.

Warm up the top end of all blanking and piercing punches to a dark blue after they have been tempered; this will allow them to be burred over when finally fitted.

If it is required to bend a file in order to get at an awkward part, heat it to a dull red, bend it to the desired radius; then re-heat it to a bright red and quench in water. The pretty, mottled finish which is seen on some tools is obtained by skin-hardening with cyanide or ferrocyanide of potassium and quenching in brine.

Die Setting and Testing.—The setting of a press tool for operating requires care and precision. It must always be borne in mind that if the tool is wrongly set or out of alignment, one operation under power can ruin the whole tool and reduce it to scrap. A tool is always mounted into the press in an assembled state, *i.e.* with the punch entered into the die. The press is pulled round with the tommy bar until the ram is at the lowest part of the stroke, and the ram screw adjusted until the tool will just pass underneath, or if it is too low, it is built up with a bolster. The spigot cap is lightly bolted into position and parallel strips placed between the underside of the punch and the top of the stripper. The press ram can then be screwed down to ensure the top of the tool being in direct contact with the bottom of the ram. The spigot-retaining cap, or screw in the case of a hand press, is then tightened up. Clamps are now placed on the bottom part of the tool, but at first they are only lightly bolted down to the press bed. The parallel strips are now removed, and the press pulled round by hand; at the same time the amount by which the punch is entering the die is carefully checked. When all appears clear, the clamp bolts holding the tool down are given another turn, and the press pulled round again by hand, and so on until the clamp bolts are very tight.

The safest way, now, is to take a couple of turns upwards on the ram screw, to bring the punch clear of the die when it is being operated. In the case of a blanking tool, the material can now be inserted, and the catch tripped so that the tool can operate for one blow. In all probability, the punch will not hit the material, and a slight turn downwards must now be taken on the ram screw, and the press again operated, the process

being repeated until a blank is struck. To the experienced man the first blank tells him much about the tool. If it is a good clean blank, without burr, the tool can be regarded as satisfactory. Should the blank show bright polished spots, giving one the impression that it has been forced through the die, then there is insufficient die clearance. Whenever the blank shows this fault, the die must be " eased " by grinding or a stone. If the blank shows a heavy burr all round without any polish, the die clearance is too much. When the blank shows a burr on one side, and polish on the other, then the tool is out of alignment, and it requires re-setting in the press.

CHAPTER 16

HEAT-TREATMENT OF WROUGHT ALUMINIUM

UNLESS aluminium alloys are subjected to the correct heat-treatment it is impossible to obtain the maximum physical properties and the best working conditions, and for this reason it is important for every sheet-metal worker to have a knowledge of this rather specialised section of the industry. The following information, made available by the courtesy of the Wrought Light Alloys Development Association, provides a very comprehensive survey of the various treatments applicable to the wrought aluminium alloys from which sheet is made. It does not, however, cover the range of cast alloys.

The term " heat-treatment " may be taken to include all operations in which changes in temperature result in a change in the properties of an alloy, but it is usually confined to the operations known as *solution-treatment* (or, less correctly, " normalising ") and *precipitation-treatment* (or " artificial ageing "). These processes strengthen the metal, but *annealing* causes softening. The wrought alloys are divided into two main groups according to the means by which their maximum properties are obtained, namely, by *work-hardening* only or by a combination of working and heat-treatment.

MINIMUM MECHANICAL PROPERTIES OF WORK-HARDENED ALLOYS

Specification Number[1]	Form and Condition	·1 % Proof Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	% Elongation on 2 in.
D.T.D.213A	Three-quarter-hard sheet	9	11	Bend test usual
	Soft sheet	—	6–7·5	25–30
B.S.S.L46	Hard sheet	15	20	3
	Half-hard sheet	12	14	5
	Soft sheet	—	11	18
D.T.D.182A	Hard sheet	17	25	15
	Soft sheet	—	20–23	20
D.T.D.310B	Hard tubes	—	15	Flattening test usual
	Soft tubes	—	9–11	Flattening and other tests
D.T.D.190	Hard tubes	17–18	25–26	Flattening test usual
	Soft tubes	10	20–23	Flattening test usual
B.S.S.L44	Soft bars and extruded sections	—	11	18
D.T.D.297	Drawn bars and extruded sections	10–15	21–25	15
	Soft bars and extruded sections	8	20	15
D.T.D.404	Hard wire and rivets	—	27	Head-forming test usual

[1] Specification numbers are used here only to indicate the range of composition; requirements as to mechanical properties must be obtained by reference to the relevant specification.

Work-hardened Alloys.—Work-hardened alloys are strengthened by cold work only, such as rolling or drawing, and any alloy can be supplied in the soft condition or in various "tempers" up to hard, intermediate strengths being indicated by *half-hard*, *quarter-hard*, etc. The degree of hardening is obtained by cold-working the metal by a suitable amount after annealing. The table on p. 321 gives mechanical properties of some representative alloys in the annealed and work-hardened conditions.

Heat-treatable Alloys.—From the earliest type of Duralumin, a whole series of heat-treatable alloys has been developed, some of which *age-harden* spontaneously, while others require a tempering treatment to attain their full strength. Alloys of both these types are usually supplied in the heat-treated condition. In some instances material may be supplied annealed or fully softened and, more rarely, in the rolled, drawn or extruded condition. Generally speaking, the heat-treatable alloys must not be used in any of these conditions and must in such cases be heat-treated by the user. The strength requirements of some typical heat-treated alloys taken from current specifications are summarised in the following table.

MINIMUM MECHANICAL PROPERTIES OF HEAT-TREATED ALLOYS (BASED ON SPECIFICATIONS)

Specification Number	Form and Condition	0·1 Proof Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation on 2 in.
B.S.S 5L3	Heat-treated sheet and strip	14·5–15[1]	25	15[2]
B.S.S 2L38	Al-coated heat-treated sheet and strip	13·5	24	15[2]
B.S.S L47	Al-coated heat-treated sheet and strip	19	25	8[2]
D.T.D.346	Soft sheet and strip	—	11	20[2]
	Heat-treated sheet and strip	16–22[1]	22–25[1]	10–16[1]
D.T.D.356	Fully heat-treated sheet and strip		27	8[2]
D.T.D.390	Al-coated heat-treated sheet and strip		25	15
D.T.D 546	Al-coated fully heat-treated sheet and strip		27	8
D.T.D.603	Heat-treated sheet and strip	16	26	15
D.T.D 610	Al-coated heat-treated sheet and strip	15	25	15
D.T.D.646	Fully heat-treated sheet and strip	23	28	8
B.S.S.6L1 and 2L39	Heat-treated bars and sections	10·5–15[1]	20–25[1]	8–15[1]
B.S.S.2L40 and L45	Heat-treated bars and sections	17–21[1]	23–27[1]	6–10[1]
B.S.S.4L25	Heat-treated forgings and bars	14	22–24[1]	8–15[1]
D.T.D.130A and 410	Heat-treated bars	17–21[1]	23–27[1]	8–10[1]
D.T.D.363A	Heat-treated bars	27	33	8
D.T.D.364A	Heat-treated bars	24–26[1]	28–30[1]	8
D.T.D.423A	Heat-treated bars	16–17[1]	21–22[1]	8
D.T.D.433	Solution-treated bars	10	17	15
B.S.S 5T4	Heat-treated and cold-worked tubes	19[3]	26	8–12·5
D.T.D.464	Heat-treated tubes	23[3]	28	6–10
B.S.S.2L37	Heat-treated rivets		25	

[1] The mechanical properties depend, in some cases, on the dimensions of the material, and this table indicates only the range covered by the standard specifications, which must be consulted for detailed requirements.

[2] Only on material thicker than 12 gauge; otherwise bend test. [3] 2% proof stress.

Full Heat-treatment.—Heat-treatment involves three distinct phases:

(1) Heating the alloy for the requisite time.

(2) Cooling it rapidly from the temperature, usually by quenching.

(3) Ageing, either spontaneously at ordinary temperatures or as a result of low-temperature reheating.

The first two operations together are known as "solution-treatment". Formerly, this treatment was referred to as "normalising," but this word has a different meaning in the heat-treatment of steel, and it is not therefore applied to light alloys today. The spontaneous hardening of

CONDITIONS FOR SOLUTION-TREATMENT OF WROUGHT ALUMINIUM ALLOYS

Specification Numbers	Form	Temperature Range[1] (° C.)	Quenching Medium
B.S.S.5L3	Sheet and strip	485–505	Water or oil
B.S.S.395	Sheet and strip	470–490	Water or oil
D.T.D.346	Sheet and strip	510–520	Water or oil
D.T.D.356	Sheet and strip	500–520	Water or oil
D.T.D.603	Sheet and strip	500–510	Water or oil
D.T.D.646	Sheet and strip	500–510	Water or oil
B.S.S.2L38	Aluminium-coated sheet and coils	485–505	Water or oil
B.S.S.AL47	Aluminium-coated sheet and coils	500–515	Water or oil
B.S.S.BL47	Aluminium-coated sheet and coils	525–535	Water or oil
D.T.D.390	Aluminium-coated sheet and coils	480–500	Water or oil
D.T.D.546	Aluminium-coated sheet	500–510	Water or oil
D.T.D.610	Aluminium-coated sheet	500–510	Water or oil
B.S.S.396	Tubes	470–490	Water or oil
B.S.S.5T4	Tubes	485–505	Water or oil
D.T.D.220	Tubes	525–535	Water or oil
D.T.D.273	Tubes	480–500	Water or oil
D.T.D.450	Tubes	520–530	Water or oil
D.T.D.460	Tubes	520–530	Water or oil
D.T.D.464	Tubes	495–520	Water or oil
D.T.D.520	Tubes	485–505	Water or oil
B.S.S.2L37	Rivets	485–505	Water or oil
D.T.D.327	Rivets	480–500	Water or oil
B.S.S.6L1, 2L39	Extrusions[2] and forgings	485–505	Water or oil
B.S.S.A2L40, AL45	Extrusions[2] and forgings	500–515	Water or oil
B.S.S.B2L40, BL45	Extrusions[2] and forgings	525–535	Water or oil
D.T.D.364A	Extrusions[2] and forgings	500–520	Water or oil
D.T.D.423A, 443	Extrusions[2] and forgings	520–530	Water or oil
D.T.D.130A, 410	Extrusions[2] and forgings	515–535	Water or oil
B.S.S.2L42	Forgings	510–535	Water
B.S.S.532	Forgings	480–490	Water or oil
B.S.S.533	Forgings	505–520	Water or oil
D.T.D.147	Airscrew forgings	470–490	Water or oil
D.T.D.150A	Airscrew forgings	485–505	Water or oil
D.T.D.184	Airscrew forgings	525–535	Water
D.T.D.246A	Crankcase forgings	515–525	Cool in air
B.S.S.4L25	Bars for forging and forgings	490–525	Water or oil[3]
D.T.D.324	Forgings	520–535	Water or oil
D.T.D.363A	Extrusions[2]	450–470	Water or oil
B.S.S.477	Bars	480–490	Water or oil
B.S.S.478	Bars	505–515	Water or oil[3]

[1] These temperatures are averages for alloys covered by the specification, and in cases of doubt reference must be made to the supplier.
[2] Extrusions = bars for machining or forging and extruded sections.
[3] Hot water may be used to reduce distortion.

certain alloys is known as *age-hardening*. The low-temperature hardening operation is correctly called *precipitation-treatment* or *temper-hardening*, while, less correctly, it is sometimes known as *artificial ageing*.

Solution-treatment.—In every case the maximum hardening effect is obtained only when the solution-treatment temperature is as high as practicable, but the upper temperature permitted is limited by the risk of cracking due to partial melting of the metal. The temperature used in practice must be somewhat below the theoretical maximum, due to slight variations in the composition of the alloy and to lack of uniformity in the temperature distribution within the furnace. Figures specified for a particular alloy must therefore be rigorously maintained. Temperatures that are too low result in low mechanical properties.

Severe overheating ("burning") may be revealed as blisters on the surface, and slight overheating results in cracks when a bend test is applied. Dark spots may be visible in the fracture of a test piece or on the surface. It is sometimes alleged that overheating may be corrected by long re-heating at the correct temperature, but, with rare exceptions, overheated metal is fit only for scrap.

The correct solution-treatment temperatures for each alloy are given in the table on p. 323. It should be noted that material supplied to B.S. Specifications 2L40, L45 and L47 may include alloys of different chemical composition, necessitating different solution-treatment temperatures. The two types of alloy to each specification are therefore indicated by the letters (A) or (B) placed before the specification number. Type A alloys have a copper content exceeding 3·0 per cent., while the copper in the B alloys is less than this figure.

APPROXIMATE GUIDE TO HEATING TIMES FOR THE SOLUTION-TREATMENT OF ALUMINIUM ALLOYS

Section	Time
Sheet or strip up to 26 s.w.g. (up to ·018 in.)	6–10 minutes
Sheet or strip 22–24 s.w.g. (·028–·022 in.)	10–14 minutes
Sheet or strip 18–20 s.w.g. (·048–·036 in.)	14–20 minutes
Sheet or strip 14–16 s.w.g. (·080–·064 in.)	18–22 minutes
Sheet or strip 10–12 s.w.g. (·128–·104 in.)	22–28 minutes
Sheet or strip 6–8 s.w.g. (·192–·160 in.)	28–34 minutes
Sheet or strip 3–5 s.w.g. (·252–·212 in.)	30–38 minutes
Bars or extrusions up to ·5 in. diameter	30 minutes
Bars or extrusions 0·5–1 in. diameter	45 minutes
Bars or extrusions — for each additional 1 in.	45 minutes

The above times are for work immersed in a salt bath. For air furnaces there must be added to these the period necessary to bring the load up to the required temperature.

Soaking times cannot be given with the same accuracy as temperatures, owing to differences in the furnaces employed and in the load and spacing of the work. The figures in the table above, however, provide an

approximate guide to the time necessary for materials of different thicknesses. Soaking times should be found by test for specific materials and strictly adhered to. Prolonged heating or repeated solution treatment of aluminium-coated sheet is particularly harmful, since the alloying constituents diffuse from the core into the pure aluminium coating and thus reduce the resistance to corrosion.

Quenching.—The normal method of quenching is to plunge the hot metal into cold water, though, owing to the variation in concentration resulting from differences in temperature between different parts of the material during the quenching operation, such rapid cooling causes distortion of the work. This can be reduced by increasing the angle at which the metal enters the quenching bath. In the case of long sections, tubes, etc., it is recommended that they should be quenched vertically if facilities for this exist. Other methods employed to reduce distortion are decreasing the cooling rate either by using hot water or oil as the quenching medium or, for thin material, using an air-blast or water-spray. All these latter methods, however, have disadvantages ; warping of the work may be less, but certain alloys are left liable to intercrystalline corrosion by sea-water, etc.

An important factor affecting the cooling rate is, naturally, the period of time elapsing between solution-treatment and quenching ; and it has recently been established that for sheet material up to approximately ·10 in. thickness it is necessary that the quenching operation shall follow not more than 10 seconds after removal from the heating furnace if the maximum resistance to intercrystalline corrosion is to be ensured.

In the United States, spray-quenching is being increasingly used for sheet. The hot sheet is placed end-on in a stream of " mist " formed by blowing cold air over suitable water-atomising jets which, although they may be situated in the cooling chamber, do not " play " directly on to the hot metal. Using this method, a uniform rate of cooling is obtained, but for aircraft components this method has not yet received A.I.D. approval and, except for heavy forgings, cold-water quenching remains customary practice. Heavy forgings and heavy, intricate sections are generally quenched either in boiling water or in oil, in order to minimise quenching stresses and subsequent distortion. In certain cases, part-machining is recommended before heat-treatment to improve the mechanical properties and stress distribution. *Oil-quenching should not be used for metal heated in a salt bath,* because of the risk of fire when hot nitrate makes contact with the oil.

Precipitation and Ageing Treatments.—In all age-hardening alloys, the strength begins to increase shortly after quenching, but some alloys harden more rapidly and to a greater extent than others. These are termed *natural ageing* alloys, and their full strength is reached after 4–5 days at normal shop temperatures. Hardening is delayed by keeping the quenched material just below normal temperature, and hence more than 5 days may be required in cold weather before the maximum strength is

obtained. As age-hardening reduces ductility, any appreciable cold working must be performed while the metal is still soft. This working may include shaping or forming of sheet, strip and sections, or the removal of distortion, such as by stretching, roll flattening, or straightening by hand or in a press. Working of the natural-ageing alloys must be completed within 2 hours of quenching, or, for intricate pressings, within 30 minutes.

Age-hardening may be delayed by storing heat-treated material at low temperatures. Refrigerated storing, usually at from − 6° to − 10°. C., is used for strip, sheet and rivets, and the work may be kept for periods up to 4 days after heat-treatment in order to allow economical runs of work to be obtained. If refrigerated storing is not used to prevent age-hardening, it is necessary to re-solution-treat the metal before further work is possible.

Artificial Ageing.—The artificial-ageing alloys harden slightly at normal temperatures after solution-treatment, but maximum mechanical properties, particularly proof stress, are not obtained even after long standing. Precipitation treatment (or *artificial ageing*) involves heating the quenched alloy to a temperature between 130° to 200° C. for a suitable period, according to the composition of the alloy and the properties required. Some double-treatment alloys are able to withstand a certain amount of cold work after quenching and ageing at room temperature, so that re-solution treatment is not required unless the working operations are severe. Precipitation treatment is then carried out at any time to obtain maximum strength.

CONDITIONS FOR PRECIPITATION-TREATMENT

Specification Numbers	Temperature (° C.)	
Sheet and Strip		The time required to produce full ageing in a given alloy may be as long as 20 hours or as short as 2 hours, depending upon the temperature of precipitation, the time being a maximum at the lowest temperatures.
D.T.D 346	155–175	
D.T.D.356	155–175	
B.S.S. AL47, BL47	170–185	
D.T.D.546	165–175	
D.T.D 646	165–175	
Tubes		
D.T.D.220A	165–175	The exact treatment required must be obtained from the release note covering the material, or from the supplier.
D.T.D 460	165–200	
D.T.D 464	155–200	

Precipitation-treatment temperatures are summarised in the table above, but the ageing time required depends on the alloy concerned, the temperature selected and, to some extent, on the type of furnace used. In general, for a specified degree of hardening, high temperatures require shorter times than low temperatures.

The time-and-temperature factors must be selected to give reasonably short time commensurate with accurate control. It will be appreciated

that heavy or closely packed loads of work in certain types of furnace require a considerable time before the temperature is uniform throughout the mass, and in such cases a long heating period at a comparatively low temperature is desirable. For example, an alloy may be fully aged in 2–3 hours at 190° to 200° C., but it may require up to 2 hours to bring the temperature of the load uniformly to this figure. Thus it would be advisable to use a lower temperature, say 160° C., at which the time required would be from 15–25 hours.

A.I.D. instructions covering aircraft components do not permit the accelerated ageing of alloys which age-harden naturally. It is laid down in *B.S.S.* 4*L*25 and 478, however, that for these materials (Y-alloy) ageing by boiling in water for one hour is permissible instead of 5 days at normal temperature.

The temperatures given in the table are low enough to avoid appreciable distortion—a valuable characteristic when articles are finally shaped after solution treatment. The method of cooling is relatively of small importance, but if some distortion is not undesirable, the metal may be quenched in order to increase production and to avoid a virtual lengthening of the heating period. Quenching, however, involves the inconvenience of drying the metal, and thus air cooling is more usual.

ANNEALING

Work-hardening Alloys.—Cold working of any metal, such as by rolling, drawing, pressing, beating, spinning or stamping, increases its hardness and tensile strength but reduces its ductility, and if cold working (strain-hardening) is carried too far, the metal may crack. The degree of cold working which a material will withstand depends on its composition and initial hardness.

When a cold-worked metal is heated above a certain temperature (the recrystallisation temperature), softening occurs and the process is known as *annealing*. Work-hardened alloys which have been annealed cannot be restored to their original strength except by further cold working.

It is unsatisfactory to exceed appreciably the required temperature, as this tends to increase the grain size of the metal. Prolonged soaking at or above the recrystallisation temperature is also undesirable. Excessive crystal—or grain—growth reduces the mechanical properties of the metal and may give an undesirable " orange-peel " effect on the surface when the material is subsequently worked.

It is desirable to obtain the soft fine-grained material required by heating for as short a time as possible, but abnormally short annealing times make accurate control somewhat difficult. Rapid heating to the required temperature is important, as slow heating to the annealing temperature favours grain growth. The commercial annealing conditions for the strain-hardened alloys are summarised below : it will be noted that the temperatures are lower and the limits wider than those necessary for the full treatment of the age-hardening alloys.

ANNEALING CONDITIONS FOR WORK-HARDENED ALUMINIUM ALLOYS

Specification Numbers	Temperature Preferred (° C.)	Temperature Range (° C.)	Time
B.S.S.2L4, 2L16, 2L17, L34, L36, 4T9	340	320–360	Sufficient to reach uniformity
D.T.D.213A	370	350–390	
B.S.L44, L46	340	320–360	
D.T.D.182A, 297	390	370–420	

Annealing of Heat-treated Alloys.—The annealing of heat-treated alloys is more complex than that of strain-hardened material, for the hardness may be due to heat-treatment or cold working or both. Alloys which have been work-hardened, either after solution treatment or after annealing, require a procedure similar to that for the non heat-treatable alloys, but special precautions are necessary to avoid age-hardening.

Softening of heat-treated alloys which have been work-hardened after annealing is carried out or obtained by heating to 340° C. ± 10 per cent. The soaking time usually allowed is 1 hour. Sometimes temperatures up to 365° C. are used, but greater care and better control of cooling are required to reduce hardening effects.

As even the lowest temperatures specified may result in slight age-hardening, it is necessary to cool the metal slowly, and, in general, the slower the cooling the softer the material becomes and the longer it stays comparatively soft. Even after slow cooling the natural ageing alloys may show slight hardening after 4 or 5 days; hence any further working should be completed within that time, and preferably within 24 hours.

Although alloys which have been fully heat-treated, with or without work-hardening in addition, are softened sufficiently for most purposes by the above treatment, full annealing of material in the heat-treated condition requires a higher temperature. This must, of course, be followed by slow cooling, in order to avoid any age-hardening. This may be called *super-annealing* and entails soaking the metal at 400° to 425° C. for at least 1 hour, followed by slow cooling at about 15° C. per hour down to 320° C., after which the rate of cooling is immaterial.

In general, longer soaking times and slower cooling result in greater softening, but "over-annealing" is not desirable. Unduly long soaking times are particularly harmful to the aluminium-clad materials, owing to diffusion of alloying constituents into the coating and also to the greater tendency to grain growth of the pure aluminium. The strength of heat-treated metal which has been softened by annealing or super-annealing must be restored by the appropriate re-solution-treatment before the parts go into service.

WORKSHOP PRACTICE

The following notes on workshop practice deal with temperature, control of materials, degreasing the work, loading, quenching, refrigerated storing, stove enamelling and heat-treatment of aircraft components.

Temperatures.—The temperatures must not be above the maximum, nor below the minimum figures specified, but the furnace or bath is usually kept at the upper limit before loading. It is essential that the thermocouple is in such a position that it truly records the temperature of the work rather than the temperature of some part of the furnace. The soaking period must be measured from the time when the temperature reaches the minimum permitted. In forced-air circulation furnaces with two thermocouples, this point is shown when the two records coincide, while in other furnaces there should be a " load couple " in contact with the work.

Checking.—Inspection and checking are necessary to maintain instruments at the required accuracy, and there is expert assistance available from the instrument makers. Not only should the accuracy of instruments be checked regularly, but the wiring, etc., must be examined for faulty insulation, dirty connections, or corrosion. Weekly checking is desirable, and if inaccuracies are found, re-calibration must be carried out before further material is treated.

Further, temperature distribution in furnaces and salt baths must be checked by independent thermocouples when the equipment is first installed, and at regular intervals afterwards. A suitable filing system for recorder charts should be provided to allow the treatment of any particular load to be checked.

Control of Materials.—Equally important is the necessity of checking the properties of the material under treatment. Control samples, therefore, should be wired to the parts being treated, as nearly as possible in the centre of the work, and should be quenched at the same time as the parts.

If the work is being solution-treated in batches, a control sample must be solution-treated with each batch. In the case of aircraft components, A.I.D. requirements will be satisfied, when solution-treatment is continued throughout the working day, if one control sample is solution-treated in the morning and another in the afternoon. All the control samples must be aged at room temperature for 5 days, and it is preferable that tests on the selected control samples should be made as soon as possible after the expiration of the 5-day ageing period. At least one of the samples heat-treated each week must be mechanically tested, and the other samples hardness-tested.

The hardness test is generally used as a quick method of testing the uniformity of batches of materials. It should not be regarded as a qualitative test, nor should it be used on clad materials. When Duralumin components are treated, the control samples must be cut from sheet or strip Duralumin which has been proved by the manufacturers to meet specification requirements.

For artificially aged alloys, full specification tests must be performed on a sample solution-treated and aged with each batch of components treated, though in certain cases the A.I.D. inspector is empowered to reduce this requirement to a minimum of two full tests each week.

Degreasing.—Removal of dirt and grease is particularly important before work is immersed in a salt bath. Oil and similar substances in contact with molten nitrate cause local overheating, especially where grease, etc., has collected in pockets or in cup-shaped articles. This local temperature increase may cause blistering or partial melting of the metal. Distortion appears to be greater when material is not degreased before treatment. Degreasing by a solvent (such as trichlorethylene) is common practice, but if chemical cleaning is used, the work must be dried completely, otherwise an explosion may occur when the moisture makes contact with the molten salt.

Loading.—The light alloys are soft when they are hot—hence care in handling is necessary to avoid surface scratches, etc., and also distortion or deformation of the metal due to its own weight.

Closely-packed loads of sheet, strip or sections are undesirable because of the inequalities of temperature through the load, the lengthy heating time required, and the slower quench obtained. The size of the load is related to the heat capacity of the furnace; hence alterations must not be made except under strict control.

The metal under treatment must not impede the free circulation of the liquid salt in salt baths, or of the air in muffle furnaces, or of the water in the quench tank. Sheets must be held vertically, and it is preferable to suspend light sections and tubes of large overall dimensions vertically whenever possible, in order to reduce distortion.

Sheets, pressings, etc., may be suspended in salt baths by wires passing through small holes, and when such holes cannot be used the work should be supported by thin aluminium or aluminium alloy wires or strips. Light pressings or thin sheets may develop cracks if they are held by tightly bound wires. When heated in a salt bath, the metal must be immersed below the surface of the salt, and must not be allowed to touch the sides or bottom. If a grid is fitted to prevent such contact, the thermocouple must be situated within the working space, not between the grid and the sides of the bath.

Some agitation of the bath is necessary in order to prevent air being entrapped in pressings, etc. Signs of such entrapped air are provided by bubbles rising to the surface for some minutes after the metal has been submerged. If the air remains trapped, a slight increase in the heating time may be necessary.

It is not possible to give definite figures for spacing, but it has been found that sheets 12 ft. by 4 ft. by ·040 in. thick can be spaced about ¾ in. apart, while similar sheets ·064 in. thick require a minimum of approximately 1¼ in. Correct spacing is particularly important during precipitation treatment for sheet, strip, pressings, forgings, and rivets alike.

Rivets are heat-treated either in air furnaces or in salt baths, and should be held in a container to allow easy removal for quenching. A container which can be immersed in a salt bath without allowing contact between the rivets and the molten nitrate is preferred, for otherwise appreciable ageing may take place during removal of the adhering salt by washing.

Containers for rivets may consist of sections of steel pipe closed at the bottom and provided with a readily removable cover. The containers are immersed in the salt with a thermocouple at the centre of the batch of rivets. The containers, which should be equipped with suitable lifting handles, must be removed quickly and the rivets quenched without delay by tipping the container.

Quenching.—Quench tanks must be situated immediately alongside or below the furnace or salt bath, with handling gear to allow quenching of the metal without any appreciable drop in temperature between its withdrawal from the heating chamber and quenching. The transfer time may vary from less than 5 seconds to not more than 20 seconds, and in such short times molten salt cannot be completely drained from the work ; the drag-out loss may therefore be serious, and the quench water becomes rapidly contaminated. The necessary rapid quench for sheets, sections and components other than heavy forgings is obtained by keeping the water temperature below 50° C If the capacity of the quench tank is small, a flow of water through the tank to a suitable cooling arrangement may be necessary.

It is impossible to avoid the formation of steam on the surface of the metal during quenching ; strong agitation of the work during immersion both reduces distortion and increases the rate of quenching. The metal must remain in the quench tank until cooling is complete. To reduce the drop in temperature during transfer to the quench tank, particularly with light-gauge material, scrap sheets of aluminium or aluminium alloy can be placed on each side of the batch : these " guard sheets " are used many times, of course.

In order to avoid corrosion due to salt residues, the quenched metal is either swilled in a second tank provided with circulating water, or a high-pressure water-spray is used to wash off all remaining nitrate. Wash-water temperature must not exceed 50° C., otherwise rapid ageing is induced. If warm water is used, washing times must be as short as possible.

Occasionally, sheets appear stained after solution-treatment, and this is often due to the use of hard water in the quenching tank. Soft water is therefore preferable, but it should be noted that softened water may not be any more suitable than hard water unless the total solids content is low.

Some of the surface discoloration of Duralumin-type alloys after quenching is due to the gradual increase in the alkalinity of the quenching water. According to British Patent 533151 (1939), small additions of acid should be made periodically to maintain the bath with an acidity below a pH value of 7. This must be carried out under laboratory control, and

it is important to ensure that the quench bath, if of steel construction, is properly protected against acid attack.

Refrigerated Storing.—The conditions specified in *British Standard 2L37* for rivets provide a guide to refrigeration requirements, namely:

Maximum storage period at atmospheric temperature ..	2 hours
Maximum storage period at 0° to − 5° C.	45 hours
Maximum storage period at − 15° to − 20° C.	150 hours

For small quantities, "cold chambers" containing a suitable refrigerant (such as solid carbon dioxide) are used, but for large sheets or quantities of pressings, automatic refrigerated stores are necessary, and such equipment may be used in conjunction with portable cold-storage boxes.

The time taken to cool from air temperature to that of the refrigerated store is often enough for appreciable ageing to take place, and for this reason a "cold quench" tank may be used to chill the metal rapidly, immediately after water-quenching. In the cold quench tank, a liquid, generally paraffin but sometimes white spirit or industrial methylated spirit, is maintained at or just below the storage temperature. After cold quenching the metal is placed in the refrigerated chamber or box.

Stove Enamelling.—It must be noted that stoving natural ageing alloys after heat-treatment and ageing results in a reduction in mechanical properties, in particular the ·1 per cent. proof stress and ultimate tensile stress, and this decrease becomes greater as the temperature and duration of heating increase. Thus, in order to avoid dangerous reduction in strength, stoving temperatures must not exceed 125° C., and this entails using low-temperature type enamels to *Specification D.T.D.* 235. Stoving at this temperature may result in a drop in the ·1 per cent. proof stress and ultimate tensile stress varying from 1½–2 tons per square inch. In the case of the precipitation-treated alloys, the stoving operations may be used to produce the required ageing.

Aircraft Components.—At present the working of the wrought aluminium alloys is, generally speaking, covered by A.I.D. regulations. Works personnel responsible for heat-treatment should therefore make certain that their practice conforms to that laid down by the A.I.D., which is detailed in *A.I.D. Inspection Instructions Nos. M.*414, *The Heat-treatment of High-tensile Wrought Aluminium Alloys; M.*426, *Control of Heat-treatment of Duralumin Rivets;* and *M.*436, *Temperature Control of Heat-treatment Processes.*